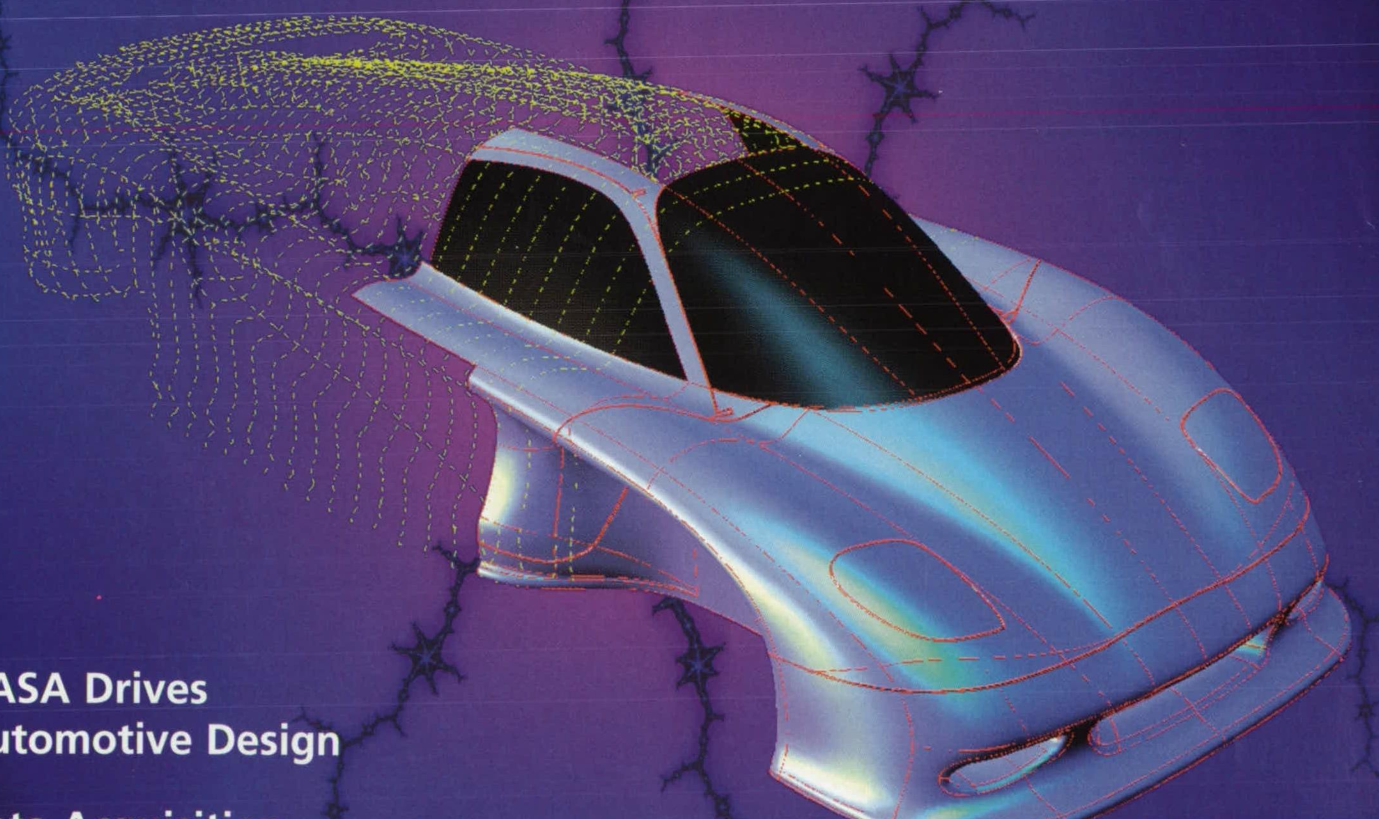
September 1998 www.nasatech.com Vol. 22 No. 9

NASA TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING



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40 NASA Fortieth Anniversary

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TECH BRIEFS

September 1998 • Vol. 22 No. 9

Features

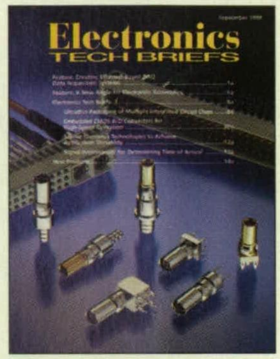
Briefs

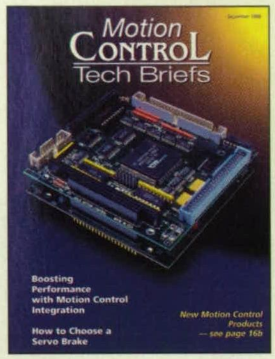
Departments

NASA's Jet Propulsion Laboratory (JPL) is conducting a neurophysiology research project in collaboration with the UCLA Brain Research Institute and Mechanical Dynamics, a software manufacturer in Ann Arbor, MI. The project is expected to yield new ways of rehabilitating patients with lower-limb paralysis, as well as preventing muscle and tissue deterioration in astronauts. The researchers are using Mechanical Dynamics' ADAMS mechanical system simulation software to develop 3D simulation of a human's walking motion, including force and joint rotation. For more information, see the Application Brief on page 28. (Image courtesy of Mechanical Dynamics)

Contents *continued*

Special Supplements





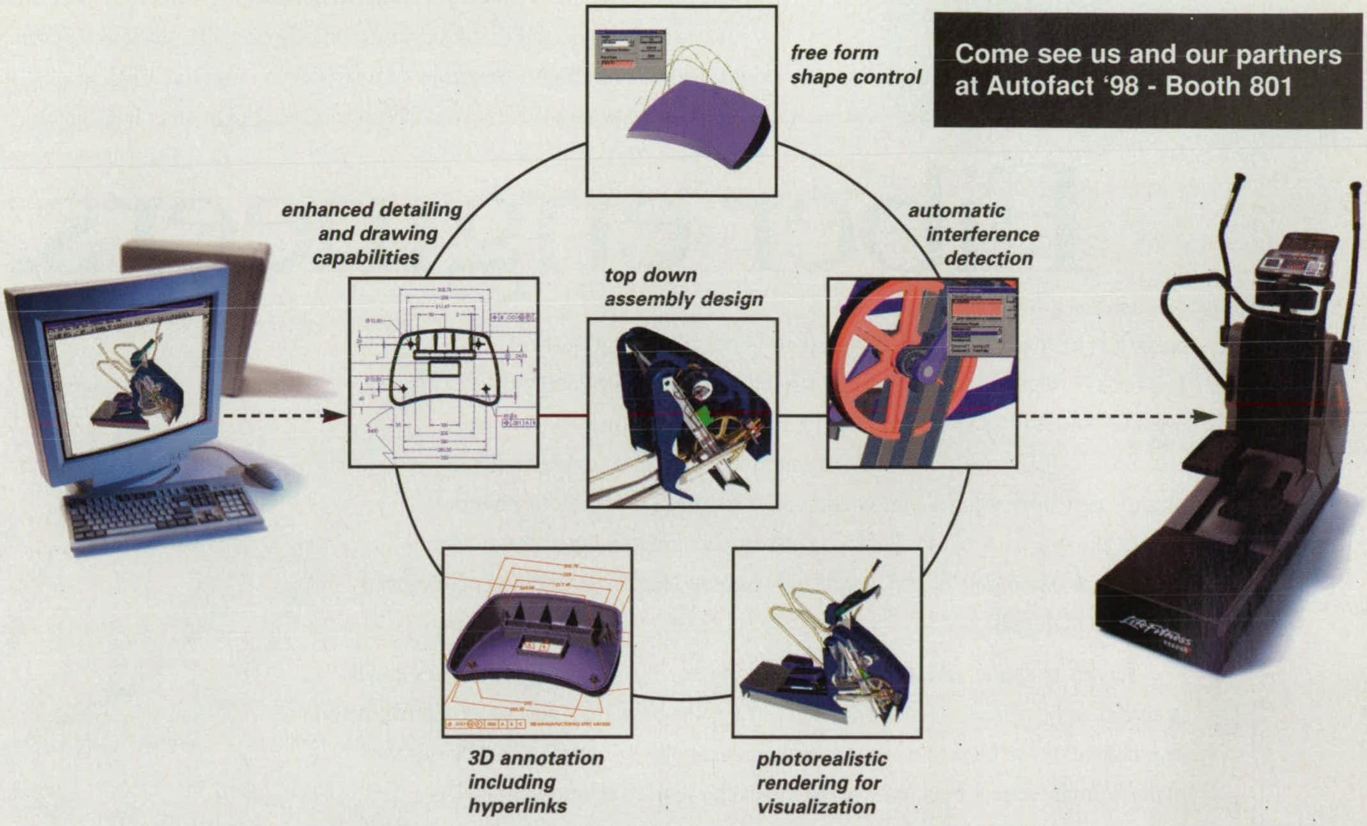
On the cover:

The Predator is a 200-mph supercharged street car with race-car handling that was designed by M&L Auto Specialists of Two Rivers, WI. Using ICEM Surf surface modeling software from ICEM Technologies, Arden Hills, MN, M&L designers reverse-engineered the original clay model they had sculpted by hand, and then imported the digitized data into ICEM Surf to build a full surface model. M&L was then able to test styling issues through realistic modeling without producing additional clay models or interim prototypes. Automotive innovations that originated with NASA technologies are highlighted in this month's coverage of NASA's 40th Anniversary, beginning on page 20.

(Image courtesy of ICEM Technologies)

SOLID THINKING IS OFTEN WHY ONE PRODUCT WORKS AND ANOTHER ONE DOESN'T.

YOUR ABILITY TO QUICKLY TRANSFORM THAT THINKING FROM AN ENGINEER'S MIND TO A FINAL PRODUCT IS ALL THAT WILL REALLY MATTER.



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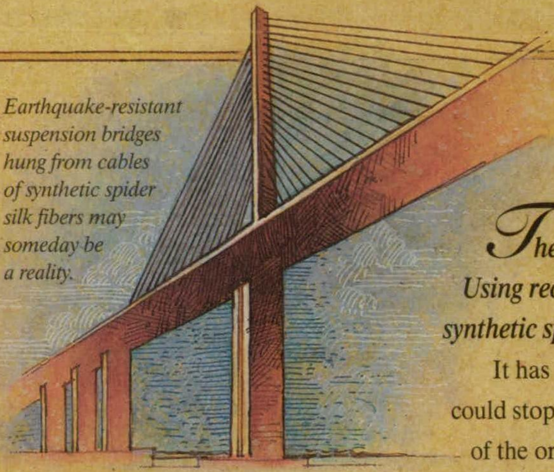


Earthquake-resistant suspension bridges hung from cables of synthetic spider silk fibers may someday be a reality.

The orb-weaving spider produces one of the world's toughest fibers. Using recombinant DNA technology, DuPont scientists have created synthetic spider silk as a model for a new generation of advanced materials.

It has been suggested that a single strand of spider silk, thick as a pencil, could stop a 747 in flight. Whatever comparison you use, the dragline silk of the orb-weaving spider is an impressive material. On an equal weight

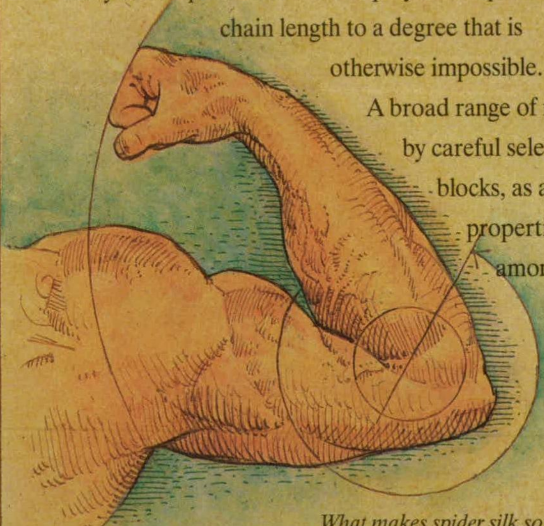
Fiber engineers,

basis, it is stronger than steel. In addition, spider silk is very elastic. It is this combination of strength and stretch that makes the energy-to-break of spider silk so high. Simply put, it is the toughest material known.

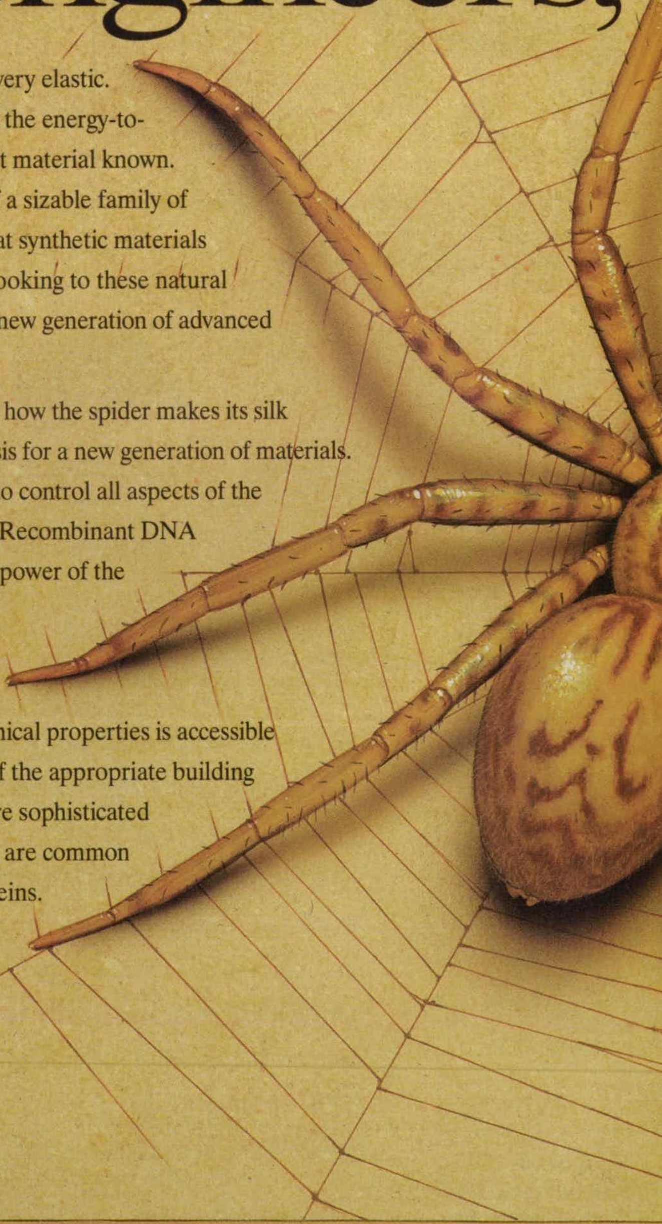
Spider silk is merely the most dramatic example of a sizable family of biopolymers possessing a combination of properties that synthetic materials cannot yet approach. At DuPont, our researchers are looking to these natural materials as paradigms for the design and synthesis of a new generation of advanced structural materials.

Secrets of spider silk, unraveled. Learning exactly how the spider makes its silk is important because this knowledge can serve as the basis for a new generation of materials. Fundamental to achieving these materials is the ability to control all aspects of the material architecture, beginning at the molecular level. Recombinant DNA technology provides a practical route to harnessing the power of the biosynthetic process to control polymer sequence and chain length to a degree that is otherwise impossible.

A broad range of mechanical properties is accessible by careful selection of the appropriate building blocks, as are more sophisticated properties that are common among proteins.



What makes spider silk so tough? A unique combination of strength and stretch.



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For More Information Circle No. 510

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC) for Technology Transfer. Call (206) 683-1005 for the FLC coordinator in your area.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
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(650) 604-0893
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
lee.duke@dfrc.nasa.gov

Goddard Space Flight Center
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George Alcorn
(301) 286-5810
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Jet Propulsion Laboratory
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Merle McKenzie
(818) 354-2577
merle.mckenzie@ccmail.jpl.nasa.gov

Johnson Space Center
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Hank Davis
(713) 483-0474
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Kennedy Space Center
Selected technological strengths: Environmental Monitoring; Sensors; Corrosion Protection; Bio-Sciences; Process Modeling; Work Planning/Control; Meteorology.
Gale Allen
(407) 867-6626
galeallen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Dr. Joseph S. Heyman
(804) 864-6006
j.s.heyman@larc.nasa.gov

Lewis Research Center
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Larry Viterna
(216) 433-3484
cto@lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(205) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
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ksharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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National Technology Transfer Center
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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

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NASA's Business Facilitators

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Dr. Jill Fabricant
Johnson Technology Commercialization Center
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(713) 335-1250

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

Joe Boeddeker
Ames Technology Commercialization Center
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(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

UpFront

Product of the Month

The F30 miniature machine vision system from Omron Electronics, Schaumburg, IL, incorporates the elements of a machine vision system — camera lens, lighting, and processor — into a compact 3 × 3 × 6" assembly that can be set up in minutes. The system was designed for basic inspection applications such as presence/absence, orientation, parts sorting, and detecting foreign material in objects as they are manufactured. Set-up requires no programming experience and is performed using a 5-button keypad. Auto and manual inspection settings are provided. It can be installed on machinery or in areas where space is minimal. Features include an adjustable shutter speed of 1/60-1/4000th of a second, processing speed of 50 milliseconds per part, sensing distance of 4 to 5", and a 2 × 2" visual field. The ring light and lens are removable, allowing them to be replaced with other lighting systems and a standard C-mount camera lens.

For More Information Circle No. 757

From Mars to the Arctic

The U.S. Coast Guard's Polar Star, one of the world's most powerful non-nuclear ice-breaking ships, was the deployment point for NASA's remotely operated underwater vehicle.

Using technology developed for the Mars Pathfinder, NASA scientists are searching for a whaling fleet lost in 1871 beneath the icy waters of the Arctic Ocean. Scientists from NASA's Ames Research Center are using an underwater telepresence remotely operated vehicle (TROV) equipped with two stereo video cameras to record underwater footage in 3D. Computer software developed for Pathfinder by the Intelligent Mechanisms Group (IMG) at Ames are being used to produce a virtual reality simulation of the underwater environment. Scientists believe these maps can be used for astrobiology hydrothermal vent research, and for marine biology and archaeology studies.

The TROV was deployed from the U.S. Coast Guard cutter Polar Star, a non-nuclear icebreaker, which is traveling north along the Canadian and Alaskan coasts to Point Barrow. During the journey, it will pass through the waters at Icy Cape, where the New Bedford whaling fleet sank in 1871 after becoming trapped in the ice and abandoned. The fleet reportedly is situated at a depth from 27 to 52 feet of water.

NASA is working with the National Oceanic and Atmospheric Administration (NOAA) West Coast and Polar Regions Undersea Research Center, Santa Clara University, and the U.S. Coast Guard to locate the sunken fleet. They also are searching for the remains of a mastodon or mammoth — extinct animals resembling giant elephants.

The expedition includes the Jeremy Project, named after Jeremy Bates, Santa Clara University's student principal investigator. The project uses NASA's latest technological advances such as robotic underwater rovers, stereo imagery, and computer software to make the marine environment more accessible.

For more information, contact the NASA Ames Public Affairs Office at 650-604-3937, or visit the web site at: http://ccf.arc.nasa.gov. Information on the Jeremy Project is available at: http://quest.arc.nasa.gov/arctic

THANKS

to all of our readers who submitted questions for our interview with NASA Administrator Daniel Goldin. Look for the interview in the December issue — the culmination of our year-long coverage of NASA's 40th Anniversary.

More Truth, Less Fiction

This summer, NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, signed an agreement with the syndicated space adventure television show, *Babylon Five*, which will give the show access to NASA scientists and technologies. JPL is looking to spread the word about its technologies and programs through entertainment media. *Babylon Five* producers expressed an interest in using real NASA technologies in future episodes.

JPL also opened a technology exhibit at Tomorrow Land, the futuristic segment at Disneyland in Anaheim, CA. Some of the NASA technologies on display include the Lunar Rover and an engineering model of the Mars Pathfinder. The display also features infrared images of the world taken from NASA spacecraft.

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

We find your magazine and web site very informative and useful. Perhaps our fellow readers can help us in our research. We are looking for a material and/or process that would economically produce very small, shaped, hardened elements in repeatable lot volumes of 10,000 to 30,000+ parts. The unit would be somewhat conical with a major diameter of approximately .045" and a length of approximately .030". It must be weldable, with an eventual hardness of RC78 to RC85. We have reviewed screw machine possibilities, but hardness requirements are difficult to meet. We currently use metal injection molding, but part cost is prohibitive. Any assistance or suggestions for alternate materials and/or processes would be appreciated.

Ken Coglon
Tally Printer Corp.
Kent, WA
425-251-6721
kenc@tally.com

We were developing an electrostatic spray system. An article in your April 1998 issue, "Electrostatic Dispersion of Fuel Drops To Reduce Soot" from Jet Propulsion Laboratory saved us time and research money. Thank you.

James R. Oates
Kingsville, TX

I'm looking for a microwave (RF) multiplexer to combine with a cold fusion experiment to see if any RF resonance makes the cold fusion work. Any help would be appreciated. Thanks.

Jon Holtzman
Genetic Enterprises
Cambridge, WI
608-423-3436

NASA Tech Briefs *is great for staying on top of the latest technology developments. It helped us in designing magnetic die pads for progressive die press operations (linear motors). Thanks.*

Robert Boswell
Ameriform Manufacturing
Carrollton, KY
rsboswell@kih.net

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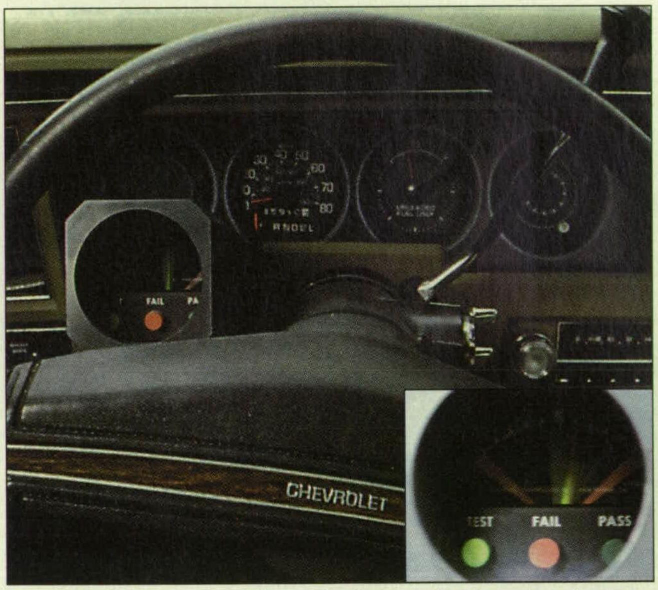
Please include your name, company (if applicable), address, and phone number or e-mail address.

This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the area of Automotive Design and Manufacturing.

1960s

A Sobering Thought

Through McDonnell Douglas Astronautics, NASA conducted a test in the mid-1960s to prepare for long-duration space missions. In the test, four men were sealed in a realistically simulated space station for 90 days to test the components of an advanced life-support system, and to obtain data on the physiological and psychological effects of confinement. One aspect of the test involved measuring the subjects' abilities to perform certain tasks and determine how their abilities were impaired by long-term confinement.



Mounted on the steering column, the CTT tests hand-eye coordination of drivers.

NASA's Ames Research Center contracted Systems Technology of Hawthorne, CA to prepare a series of tracking tests that would be accomplished by the subjects and would be used to develop an electronic system for analyzing and rating each subject's visual and motor responses.

Almost 20 years later, in the early 1980s, the technology was used in a system for determining if a driver is too drunk to drive. Under contract to the National Highway Traffic Safety Administration (NHTSA), Systems Technology developed a variation of the NASA Critical Tracking Test (CTT) device, the testing component of the Drunk Driver Warning System (DDWS). In 1983, the system was tested in two California counties where twice-convicted drunk drivers were given the choice of operating a DDWS-equipped car for six months, or taking an alternative sentence involving a fine and treatment.

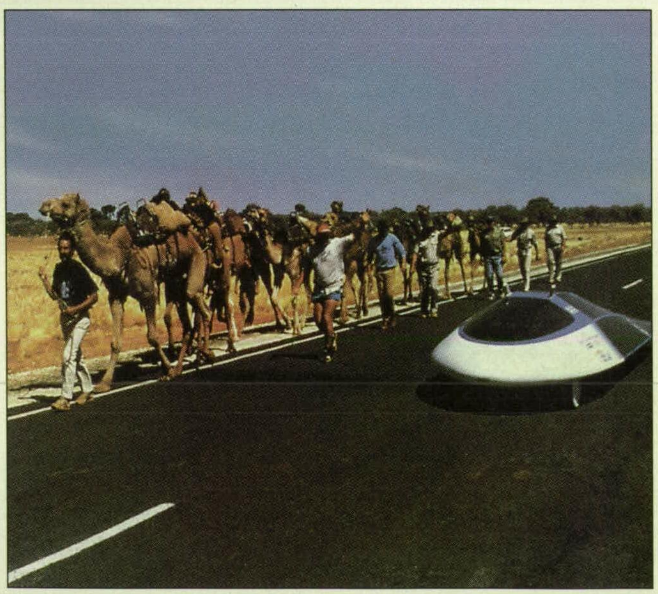
The device is designed to discourage intoxicated drivers from getting behind the wheel by advising them that they are in no condition to drive. If they drive anyway, the system warns police and other drivers. Mounted on the steering column in front of the driver, the CTT device tests eye-to-hand coordination and reaction time. When the ignition is turned on, the car's hazard lights start blinking. In order to turn them off, the driver must pass the test.

The test involves watching a needle on the CTT and keeping it centered for less than a minute by turning the steering wheel. Tests have shown that although the test sounds easy, a high failure rate occurs for drivers with blood alcohol concentrations over 0.10 percent. If the driver fails or does not take the test and drives anyway, the hazard lights remain flashing and the horn blows once every second, a signal to police and other drivers.

1980s

Soaking Up Rays

The first World Solar Challenge Race was held in 1987 in Darwin, Australia, and included solar-powered automobiles from Australia, Denmark, Germany, Japan, Pakistan, Switzerland, and the US. General Motors' Sunraycer, one of four American entries, crossed the finish line near Adelaide, South Australia, five-and-a-half days later — more than 600 miles and two-and-a-half days ahead of its closest competitor. The 1,950-mile race ran through tropical heat and humidity, desert heat, and temperate climates. The one-seat Sunraycer covered the race route at an average speed of 41.6 miles per hour, considerably better than the prior world-speed record for solar-powered land vehicles of 35.22 miles per hour.



The General Motors Sunraycer passes a camel train during the 1,950-mile trans-Australia race.

The Sunraycer is less than 20 feet long and weighs only 547 pounds with a driver. The canopy is gold-plated to reflect 90% of the visible light and 98% of infrared radiation, which holds down the temperature in hot climates. The solar array operates at 150 volts, providing up to 1,500 watts of power at noon.

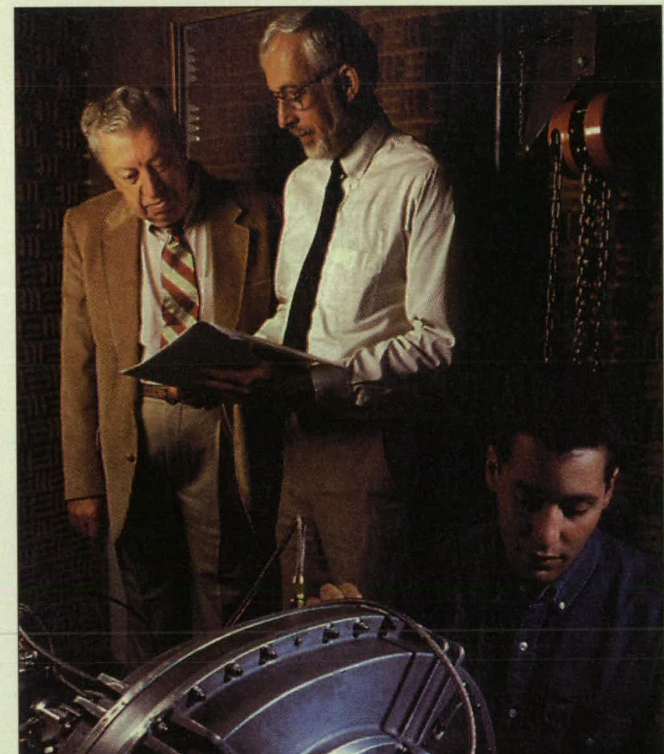
The car was designed, built, and driven by 16 General Motors operations and several suppliers, including Hughes Aircraft, a subsidiary of GM Hughes Electronics Co., and a long-time NASA contractor. Hughes designed and built the solar arrays, composed of 1,400 Hughes silicon solar cells and 3,800 gallium arsenide cells each from Applied Solar Energy Corp. and Mitsubishi Electric Corp. The photovoltaic cells convert the Sun's rays into electricity. Development of photovoltaic power was pioneered by NASA and its contractors — including Hughes — to power most of the spacecraft sent into orbit. The Sunraycer also was designed with the help of a NASA-developed computer program called VSAERO, used to calculate the aerodynamic characteristics of the car.

1990s

The Highs & Lows of Lubricants

Located in Landing, NJ, Murray United Development Corporation (MUDCO) is a research and development firm founded by Jerome L. Murray, the inventor of such products as a rotating TV antenna, electric carving knife, and dental drill. The company designed a Rotorcam engine for automobile use that also has applications in boats, aircraft, and lawn mowers.

The engine has no crankshaft, flywheel, distributor, or water pump, and it can run on virtually any kind of fuel. It is a 10" long rotary engine, with four cylinders radiating outward from a central axle like spokes on a wheel. In operation, the cylinders rotate past stationary fuel and exhaust ports and a single, centrally located spark plug.



Jerome Murray (left) and chief engineer Al Richey (center) look over test run data of the Rotorcam engine, pictured in the foreground.

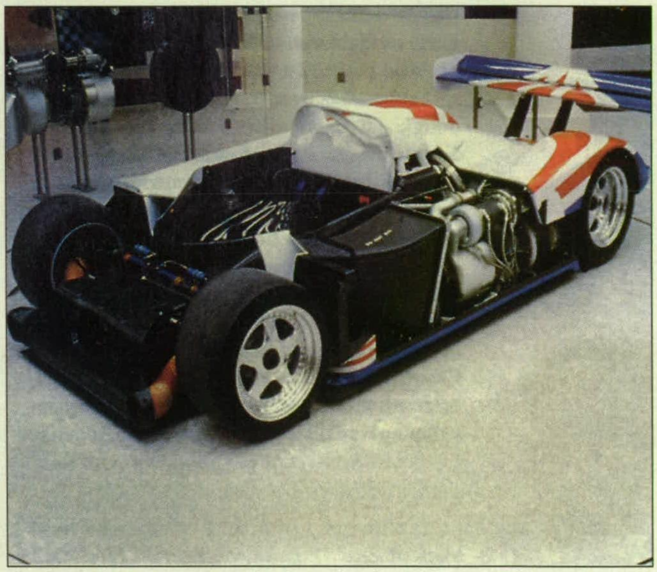
NASA technology is incorporated in the engine in the form of a valve coating. MUDCO's chief engineer, Al Richey, had learned of the development of materials that provide engine lubrication over a wide temperature range at NASA's Lewis Research Center. Plasma-sprayed PS 212 was selected by MUDCO as a coating for Rotorcam's valves to eliminate the need for a lubricant.

PS 212 contains 70% chromium carbide, 15% silver, and 15% barium fluoride/calcium fluoride. The carbide acts as a wear-resistant matrix; the silver and fluoride are low and high temperature lubricants, respectively.

Stocking Up on Power

A developer of electromechanical products for the aerospace, industrial, transportation, and utility markets, SatCon Technology Corp. of Cambridge, MA, worked on more than 30 projects with seven NASA centers through the Small Business Innovation Research (SBIR) program. Two of those projects, dealing with energy storage research, were sponsored by Lewis Research Center and Marshall Space Flight Center, and yielded technology that was used in SatCon's Flywheel Energy Storage (FES) system.

A flywheel is a chemical-free battery that harnesses energy from a rapidly spinning wheel, and stores it as electricity. The flywheel system provides 50 times the storage capacity of a lead-acid battery. In commercial use, FES systems have great potential for adding longer life and range to electric and hybrid-electric cars by providing extra power for climbing hills or accelerating, since the system recovers energy normally lost in braking. The generated electric power not used by the drive motor to power the car is stored in the flywheel.



Flywheel energy storage technology developed for NASA by SatCon Technology was used by Chrysler in the hybrid-powered Patriot Mark II race car.

Industrial applications for FES systems include providing continuous electric power to machines and operations during power failures and lightning strikes. They also can be beneficial to utilities by providing off-peak storage options for reducing power generation requirements during peak power demands.

In 1991, NASA started a focused study of the flywheel as a

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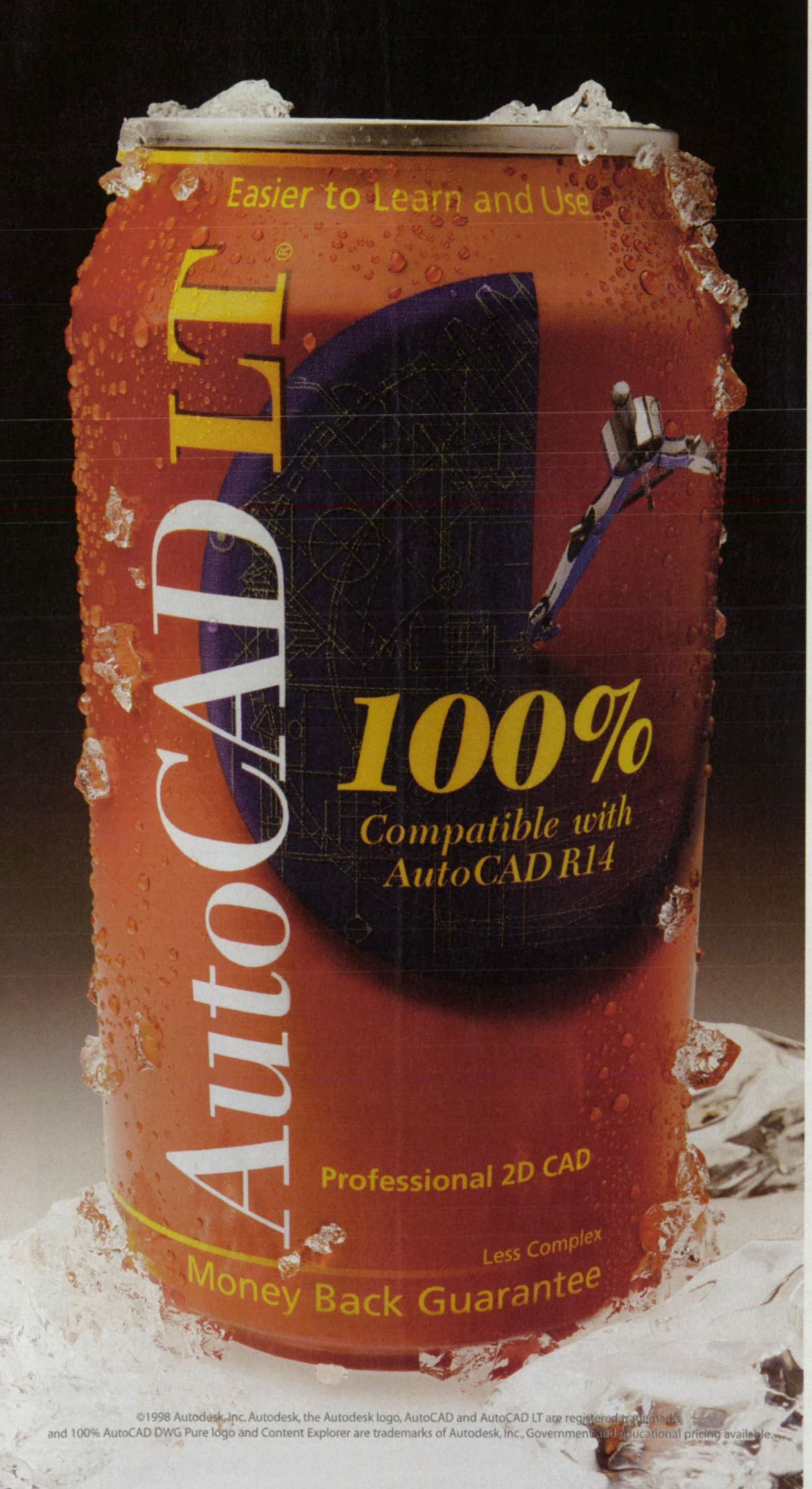

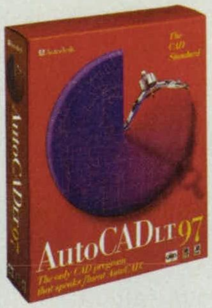

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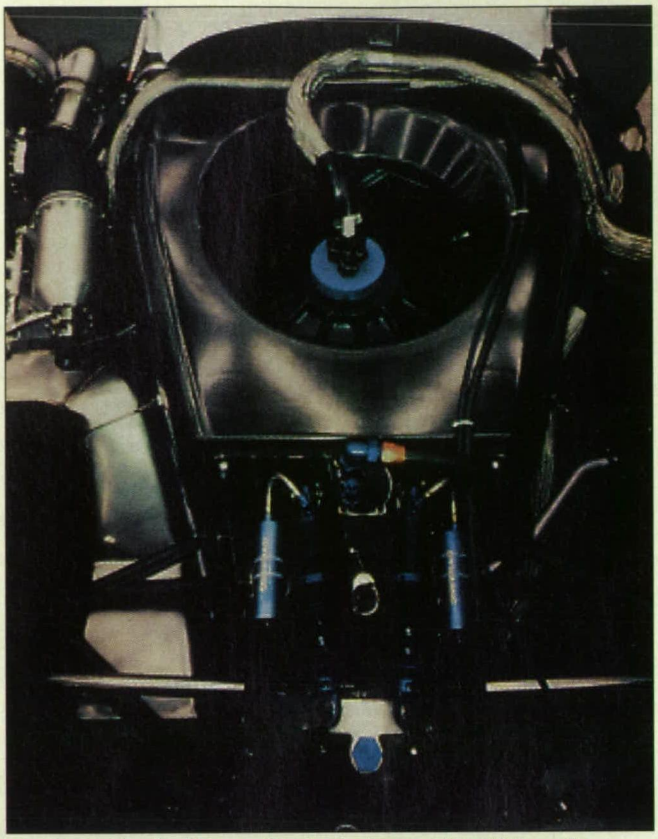

The SatCon Flywheel Energy Storage System provides 50 times the energy storage capacity of a conventional lead-acid battery.

potential battery power replacement for aerospace and commercial industries, beyond its automotive applications. SatCon supplies NASA with a number of flywheel technologies, including an Integrated Power and Attitude Control System (IPACS), which combines energy storage and spacecraft control functions in a single flywheel energy system, and spacecraft attitude control and momentum recovery. In 1995, SatCon teamed with Westinghouse Electric, Pittsburgh, PA, to commercialize SatCon's flywheel technologies. The companies will work together to provide low-voltage solutions such as energy storage, for a variety of commercial users.

Friendly Lubricants

In 1989, race car driver Edward "Buck" Parker founded Sun Coast Chemicals (SCC) in Palm Court, FL, to alleviate problems on the NASCAR racing circuit that dealt with heat and wear damage to engines and transmissions. The first SCC product was X-1R Concentrate Friction Eliminator, a commercial lubricant. In 1994, SCC was asked by Lockheed Martin Space Operations (LMSO) to develop an environmentally-friendly lubricant for a mammoth transporter.

As NASA's contractor for launch operations at Kennedy Space Center, LMSO was looking for a spray lubricant for the Mobile Launch Platform, a 6-million-pound "crawler" that moves the Space Shuttle assembly from the Vehicle Assembly Building to the launch pad at about one mile per hour. The lubricant needed to eliminate environmental drawbacks while meeting demanding lubrication requirements.

LMSO and Sun Coast developed the Crawler Track Lubricant (CTL) in eight months. It passed all Environmental Protection Agency (EPA) requirements, and now is a major part of the Crawler Preventive Maintenance Program at Kennedy.

The initial automotive lubricant has been spun-off into other products, including a Train Track Lubricant, a Penetrating Spray Lube for loosening rusted bolts and lubricating hinges, and Biodegradable Hydraulic Fluid.

A Blanket Statement

During NASCAR races, drivers often suffer burns and blisters due to the extreme heat transferred into the cockpit through the engine firewall, transmission tunnel, and floor. Exhaust pipes running under the driver's seat carry gases

Butch Stevens of BSR Products lays out a custom thermal protection system in front of the Motorsports Busch Grand National race car.

The BSR line of insulation includes floor panels, oil tank blankets, and exhaust shields.

that are 600° to 800°F away from the engine. As a result, temperatures in the driver compartment often reach dangerous levels from 140°F to 160°F. Temperatures often are hot enough to melt the soles of their right shoes (the ones pressing on the gas pedal).

Similarly, but on a larger scale, NASA's space shuttle orbiters are subjected to re-entry heat loads as high as 3000°F. The orbiters are protected by Thermal Protection System (TPS) materials inside and out, from the orbiter's outer surface to the cargo bay. Developed by Rockwell Space Systems, the TPS tiles and thermal blankets safeguard the shuttles from excessive heat.

The idea of using TPS materials to insulate heat-generating areas of stock cars came by way of a tour taken by NASCAR champion Bobby Allison at Kennedy Space Center. Former KSC Director, Jay Honeycutt, recommended to Allison that the TPS insulation could shield drivers from heat exposure. Allison contacted his colleague, Roger Penske, who was able to loan a stock car to KSC for a day of insulation retrofitting.

Penske team members, and Rockwell and NASA personnel, patterned TPS material to fit Penske Racing Inc.'s No. 2 Ford Thunderbird, driven by veteran racer Rusty Wallace. The insulation added less than four pounds to the car, and resulted in significant temperature decreases in locations where it was used. In the driver's compartment, temperatures were lowered by more than 50 degrees.

Wallace raced several times with the material and participated in an instrumented test at Daytona International Speedway in 1996. "This is a breakthrough," Wallace said. "I am totally impressed with this material. I feel that the TPS material helps the whole car run cooler, and the cooler the car, the better the performance."

BSR-TPS Products of Mooresville, NC, under a Space Act Agreement with Rockwell, now manufactures insulation kits for race car teams around the world. The cost is $1,300 apiece; the company expects to generate $1 million a year in sales. Insulation is included for areas such as under the driver's seat; between the floorpan and exhaust system on the driver's side; for insulating the oil tank; shielding the ignition system; and for installation under the driver's feet, along the side of the transmission tunnel, and behind the pedals.

Since 1976, *NASA Spinoff* has featured many down-to-earth applications of NASA technology. To learn more about how NASA technologies affect our everyday lives, visit the *Spinoff* web site at: www.sti.nasa.gov/tto/spinoff.html

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SatCon Technology	617-661-0540
Sun Coast Chemicals of Daytona	904-439-6000

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NASA-Developed Software, Including NASA's 1998 Software of the Year

Looking Ahead ...

• Auto parts sold during the Daytona 500 race bore durable markings being tested for components on the Space Shuttle. The technology has not been proven effective for space flight, but it does have a commercial market in NASCAR racing. BSR Products (see "A Blanket Statement") sells off-the-shelf and custom-made auto parts to driving teams during races. When drivers have breakdowns, they procure the parts from BSR, which tries to keep track on paper of which part was sold to which driver. The sales are sorted out after the race, along with notations as to which parts need to be reordered for inventory. With the NASA-developed compressed-symbology data-matrix marking technology — commercialized by CiMatrix of Canton, MA and its Symbology Research Center in Huntsville, AL — BSR has an inventory-control system that automatically keeps track of transactions. Members of driving teams wear an identification badge bearing a data-matrix code, as does each auto part. When a part is sold, it's scanned along with the badge of the buyer — a system similar to the bar-code process used in supermarkets. Eight parts on the Space Shuttle are being marked with the system, including the shuttle's protective tiles.

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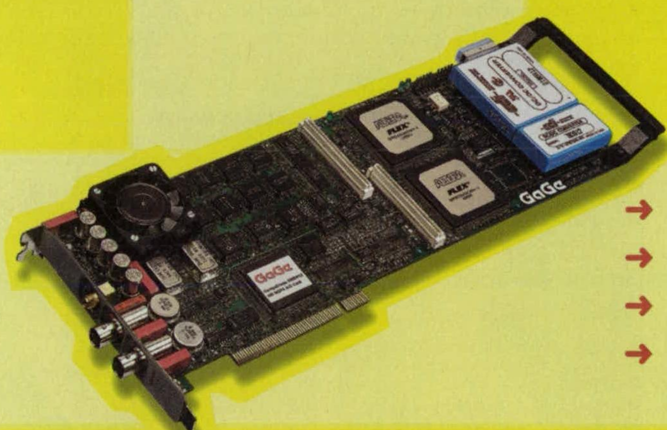

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NASA Uses Simulation Software To Help Paralysis Victims Walk

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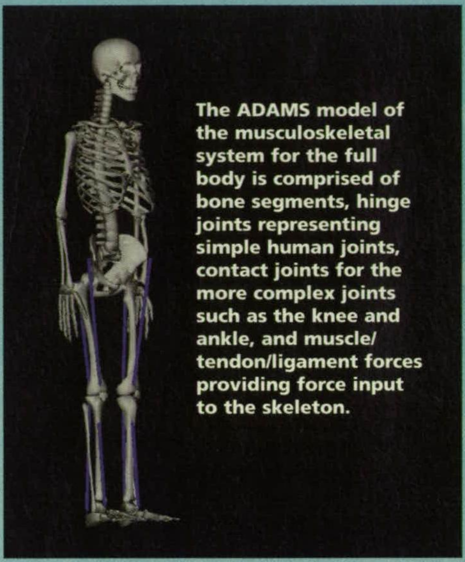
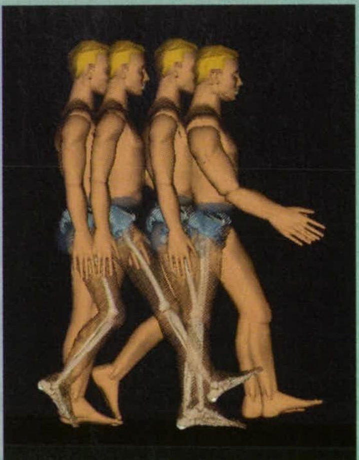


The ADAMS model of the musculoskeletal system for the full body is comprised of bone segments, hinge joints representing simple human joints, contact joints for the more complex joints such as the knee and ankle, and muscle/tendon/ligament forces providing force input to the skeleton.

A neurophysiology research project at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, uses mathematical models of the human body to study the way the brain transmits signals to lower limbs for walking, running, and other locomotion. "Investigations will aid in the development of ways to rehabilitate patients with lower-limb paralysis," explained neural repair project director Jim Weiss. Findings also will be useful in understanding and preventing muscle and tissue deterioration in astronauts during prolonged weightlessness.

According to Weiss, the initial phase of the project will focus on rehabilitation of patients disabled by stroke, spinal cord injury, and other lower-limb paralysis. JPL is working on a body-suit-like mechanism to be worn by rehabilitation patients. Force transducer technology for the system is derived from work on robotic exoskeletons developed by JPL for space station use. The body suit will have force transducers coupled with electromechanical sensors and controllers capable of exerting force and measuring resistance simultaneously with six degrees of freedom.



Sequence of animated graphic images from ADAMS shows lower-limb skeletal structure at various stages of a full walking gait, from heal-strike to toe-off. Plots and numerical readings also can be provided for parameters such as stresses and velocities on certain bones, as well as forces and torque rotations on joints.

For this neurophysiology project, researchers from JPL, the UCLA Brain Research Institute, and Mechanical Dynamics are collaborating to develop the simulation needed to analyze and predict human motion. Data generated by the exoskeleton will be fed into a 3D human model being developed in ADAMS. The resulting system is expected to provide researchers with a tool to simulate walking motion, calculate force and rotation levels at joints, pinpoint which portions of the step cycle need augmentation, and devise ways of placing less abnormal stress on muscles and bones.

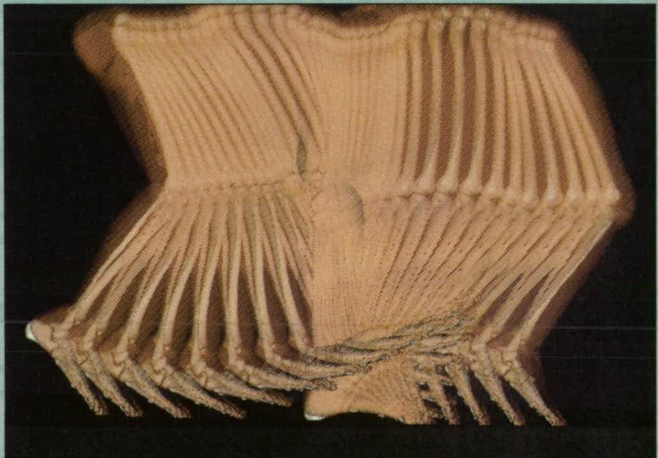
Development of the neuro-controlled musculoskeletal model uses a unique coupling of two analysis tools: the neuro-oscillator control system is simulated in Matlab software from The MathWorks of Natick, MA, coupled simultaneously to a musculoskeletal model of the full human body simulated in ADAMS. This co-simulation architecture allows collaborating scientists to develop the neuro-oscillator system and the musculoskeletal system to the level of detail necessary to capture human locomotion for both normal and spinal-injured patients.

The ADAMS model of the musculoskeletal system for the full body is comprised of bone segments, hinge joints representing simple human joints, contact joints for the more complex joints such as the knee and ankle, and muscle/tendon/ligament forces providing force input to the skeleton. The Matlab model consists of a hypothetical model of the neural network of the spinal chord.

Both ADAMS and Matlab pass data back and forth through data pipes. Data provided by the ADAMS human model consists of sensory feedback such as leg position and foot/ground contact; data from the Matlab neuro-controller are muscle activations to control walking. With this arrangement, the model can adapt to instantaneous changes in the environment, as well as to changes in gait characteristics.

Output from the model is provided in the form of a realistic animated display of the walking motion, as well as numerical readout and graphs that plot various parameters. Specific outputs in these simulations indicate ground reaction forces during various phases of foot impact, foot motion and load, ankle and joint rotation, muscle stretch and forces, limb acceleration velocity and position, and muscle activation for gait control.

For More Information Circle No. 756



Data provided by the ADAMS human model consists of sensory feedback such as leg position and foot/ground contact. Output is provided in the form of a realistic animated display of the walking motion.

Commercialization Opportunities

Automated Cargo-Tracking Transponders

Credit-card-sized electronic transponders are proposed for use in tracking cargo anywhere on Earth. The transponders with corresponding communication and data-processing system would ensure accurate up-to-date tracking, would eliminate voluminous paperwork, and eliminate unnecessary opening of cargo containers.
(See page 38.)

Optoelectronic Generation of Optical and Microwave Signals

An apparatus denoted "coupled optoelectronic oscillator" is the latest product of a continuing effort to develop photonic/electronic frequency synthesizers with low phase noise, wide tuning range, and high resolution in frequency.
(See page 50.)

Engine Monitoring Based on Normalized Vibration Spectra

An electronic engine-health-monitoring system picks up signals from vibration sensors and processes the signals to look for signs associated with incipient engine failures. A neural network is used to classify and recognize the problems.
(See page 56.)

Parallel-Processing CDMA Detector With Neural Network

A proposed improved code-division multiple-access (CDMA) detector would achieve high resistance to jamming of weak ("far") received signals by strong ("near") ones. A compact neural network would process the outputs of matched filters in such a way as to obtain optimum solutions to this near/far problem.
(See page 58.)

$MoSi_2$-Based Composite Materials for Aircraft Engines

These composite materials are undergoing development as potential strong, stiff, lightweight replacements for the nickel-based superalloys now used on aircraft engines. The most promising ones include SiC-based fibers.
(See page 62.)

Rib Valve as Shutter for Air Swirler in Combustor Nozzle

A rib valve is under consideration as a shutter in an air swirler in the fuel nozzle of a variable-geometry combustor. The valve/shutter would provide the variable-geometry airflow needed for proper functioning of the combustor under various operating conditions, including rich burn, quick quench, and lean burn.
(See page 72.)

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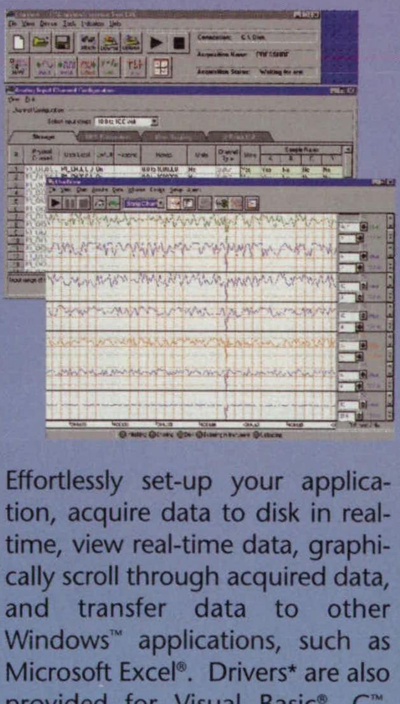

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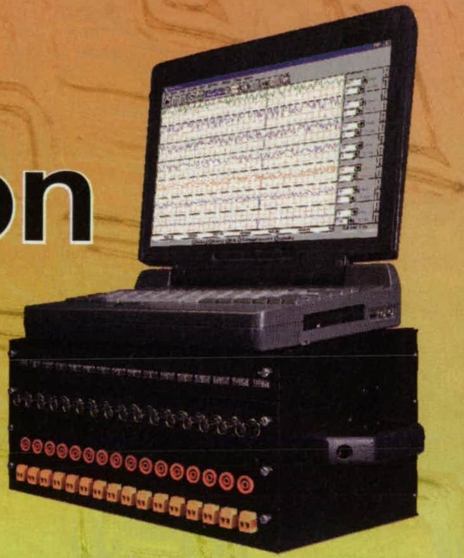

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NAVSYS Corporation, Colorado Springs, Colorado

A "smart" video camera, called the "GI-Eye," generates digital image data that are automatically tagged with geo-registration meta-data to indicate the precise position and attitude of the camera when the image was taken. This automatic georegistration streamlines the processing of the digital image data; in particular, it reduces the time needed to correlate common features in different images and enables the derivation, from the image data, of the precise three-dimensional coordinates of features in images.

The GI-Eye includes a Global Positioning System (GPS) receiver, inertial sensors (an accelerometer and a fiber-optic gyroscope), and a digital video camera. The digital image data are recorded in bit-map file format and can be stored on a compact disk read-only memory (CD-ROM) or other personal-computer-compatible mass-data-storage medium for subsequent retrieval. The georegistration meta-data are saved in an Access data base, where they are cross-referenced to the image bit-map filenames to facilitate the retrieval and processing of the image data.

The GI-View software package is designed to facilitate processing of the GI-Eye digital image data and to generate three-dimensional coordinates of features of interest from the image data base (see figure). This software package runs under Windows on a desktop or laptop personal computer. GI-View provides a point-and-click user interface for selection of features from the digital images. When multiple views of the same feature are selected,

An **Image Containing a Target** is overlaid with target information from an object data base in a typical GI-Eye display.

GI-View automatically computes the three-dimensional coordinates of that feature. The feature coordinates are saved in an Access data base to facilitate the establishment of interfaces with other Windows application programs or with Geographic Information System (GIS) software.

The GI-Eye system has been demonstrated to provide three-dimensional coordinates from the image data to with 1- to 2-meter accuracy at distances of up to 1 km from the camera. For objects that are much closer, the positions of features relative to the location of the camera can be determined to an accuracy of a few centimeters.

The GI-Eye system has been selected by the U.S. Navy for use in an advanced technology demonstration to provide real-time target coordinates on the battlefield. The GI-Eye system is also available for generating GIS attribute databases and providing point coordinates for mapping and surveying.

This work was done by Alison Brown and Randy Silva of **NAVSYS Corporation** *for* **NASA Headquarters** *under an SBIR contract to develop a GPS/inertial mapping system and for the* **Defense Advanced Research Program Agency (DARPA)** *to develop a precise targeting system. For further information, please contact:*

Alison Brown
NAVSYS Corporation
14960 Woodcarver Road
Colorado Springs, CO 80921
Tel.: (719) 481-4877
Fax: (719) 481-4908
E-mail: abrown@navsys.com
or access www.navsys.com

Refer to SBIR-0005.

Converting Particle-Fallout Data to Obscuration Levels

John F. Kennedy Space Center, Florida

A worksheet has been constructed within the Microsoft Excel software system for converting raw particle-fallout data into percentages of obscuration; that is, percentages of areas obscured by particles on surfaces. These obscuration levels are needed for assessing contamination levels in nominally clean manufacturing and assembly facilities. The raw data are obtained by an automated instrument that scans witness plates, determines the sizes of particles that have fallen onto the plates by analyzing their light-scattering characteristics, and counts the number of particles in each of six size ranges. For a given witness plate, the user enters the number of particles counted in each size range into a designated space on the worksheet. Within each size range, the unknown particle-size distribution is assumed to be characterized by a log-normal slope represented by a line that connects the cumulative counts at the limits of the size ranges. The worksheet software uses the counts and this assumed distribution to compute an overall particle-size distribution, which is then used to compute the percent obscuration.

This work was done by Christian J. Schwindt, formerly of I-Net, and Eugene N. Borson of Swales & Associates, Inc., for **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. KSC-11956*

Switching Protocol for Optical Packet Data Communication

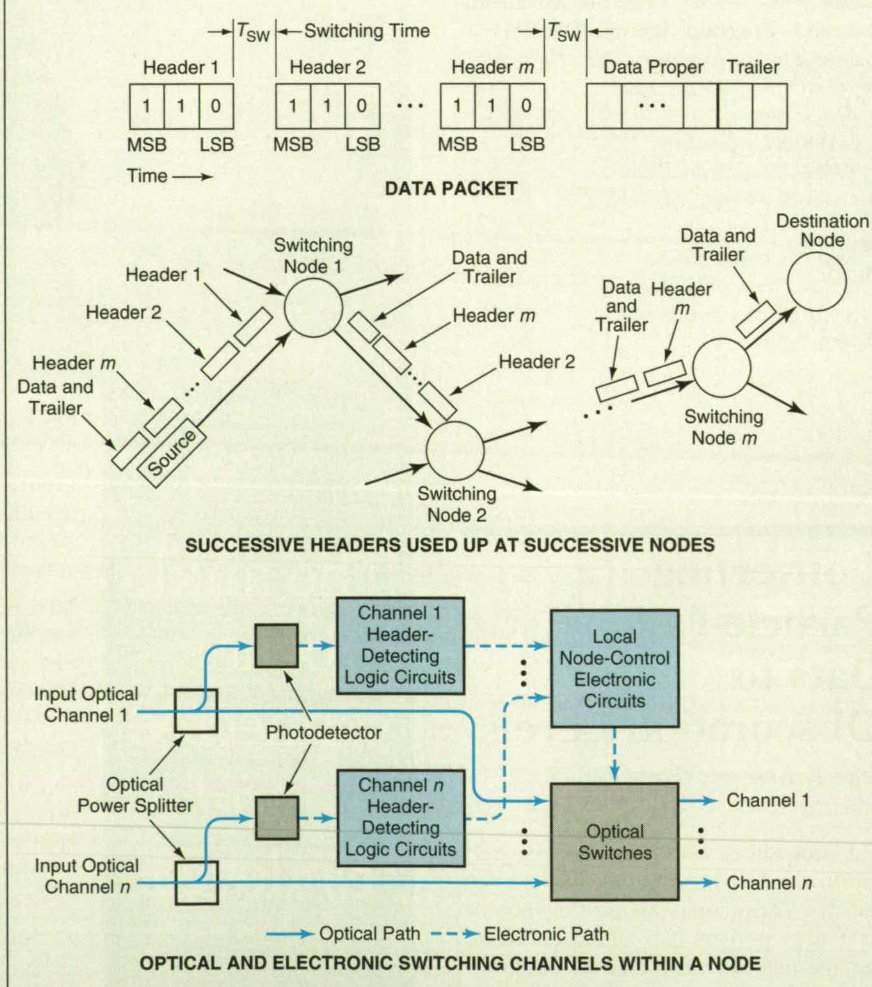
Multiple copies of headers would eliminate the need for storage of packets.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates aspects of a proposed switching protocol for optical packet data communication that would serve as an alternative to the older store-and-forward and header-first protocols. In both older protocols, it is necessary to store a single header from each packet of data during the relatively long optical-switching time (typically tens of milliseconds) needed to set up optical input and output paths within each node. In the store-and-forward protocol, there is also a need for electronic storage of the data proper at each node during the setup time. Furthermore, typical implementations of both older protocols have depended on electronic control circuitry between nodes to set up the optical paths between nodes.

The proposed protocol would eliminate the need for both (1) electronic storage of headers and data proper and (2) internode electronic control circuitry. Depending on the specific implementation, local electronic control and switching circuitry might still be needed within each node, but the destination node address needed to set up the optical paths between nodes would be transmitted optically. Each data packet would begin with m identical copies of a header, where m = the number of optical switches along the intended data path. Each copy of the header would contain the address of the destination node. The data proper would follow the headers and would be followed by a trailer.

(Continued on page 38)



Each Copy of the Header Would Blaze the Trail for the next copy to go on to the next node and would be used up in the process. Enough copies (m) of the header would be provided so that the data packet could find its way to the destination node after traveling through m switching nodes.

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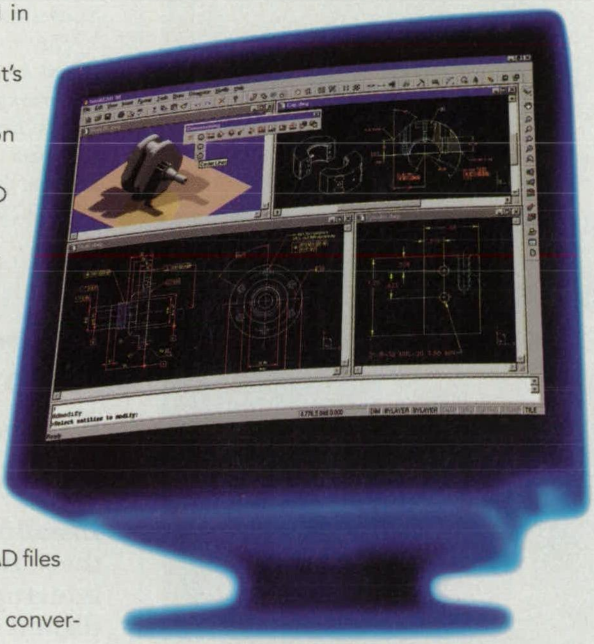

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For More Information Circle No. 517

(Continued from page 34)

Starting with the first copy of the header in a packet and working back along the packet, successive copies of the header would be consumed in setting up the optical switches within successive nodes along the path. The interval between successive copies of the header would be made long enough to allow sufficient time for optical switching to occur, in the foremost node along the path, in response to the first copy of the header to arrive there. By the time the second copy of the header had arrived at the foremost node along the path, the foremost node would be configured to transmit the header, along with the rest of the packet, to the next node. Thus, the second copy of the header to arrive at a node would be passed on to the next node, becoming the first copy to arrive there. This process would be repeated, each successive node along the path momentarily becoming the foremost node, until all m copies of the header were used up and the optical path through all m switching nodes was established. The data proper would then follow along the path, followed by the trailer. As it passed through each node along the path, the trailer would signal each node to break the optical path and await the arrival of the next header, if any.

Because of the long optical-switching times, the data in the headers could be transmitted at relatively low rates, enabling the use of correspondingly slow logic circuits within the nodes to detect headers and control the optical-switching functions. However, the data proper could still be transmitted at high rates (gigabits per second) because the data path would be all-optical.

This work was done by Steve P. Monacos of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-19522.

Automated Cargo-Tracking Transponders

Installed on cargo containers, these transponders could be interrogated from nearby or distant locations.

NASA's Jet Propulsion Laboratory, Pasadena, California

Credit-card-sized electronic transponders have been proposed for use in tracking cargo anywhere on Earth. A transponder would be carried on a cargo container, where it would act as a "smart tag." The transponder would store data on the cargo in the container and would respond to inquiries — whether local or remote — about the contents and location of the shipment. The transponder and the communication and data-processing systems with which it would interact would ensure accurate and up-to-the-minute tracking of cargo, whether the cargo was in a warehouse, train, truck, airplane, or ship. Tracking cargo in this way would eliminate the need for the voluminous paperwork now used to track cargo and would make it unnecessary to prematurely open cargo containers at transshipment points to ascertain their contents.

A transponder would contain a microprocessor and a strip of random-access

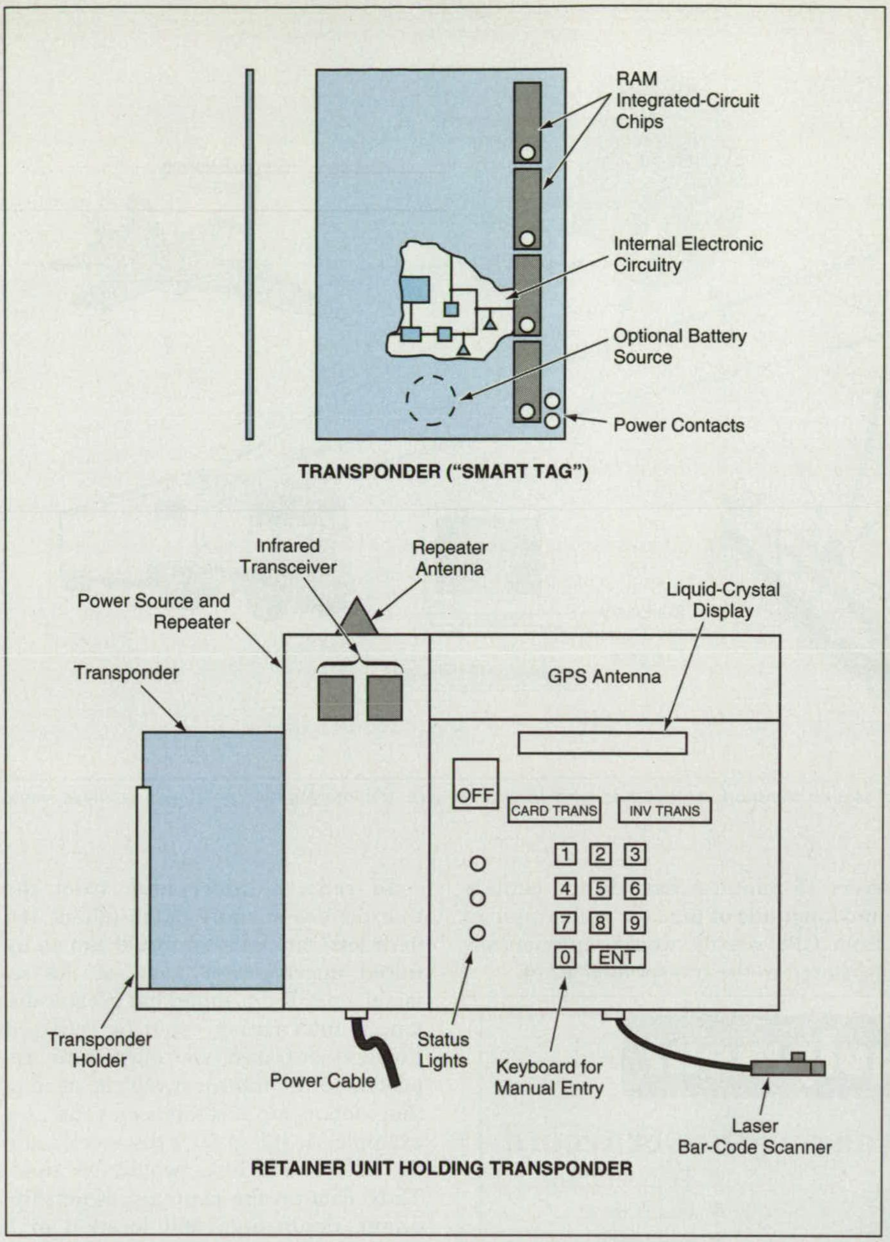


Figure 1. **RAM Chips** would be laid out in an area of about the same dimensions as those of the magnetic strip on a conventional credit card. The retainer unit would provide electric power (about 1 mW) to the transponder and would serve as an electrical interface between the transponder and the outside world. The retainer unit would be about the size of a hand calculator.

memory (RAM) integrated-circuit chips that would store the information on the cargo and its location. For limited applications, the transponder itself would be self-contained, with all the required functions [i.e., encoding, Global Positioning System (GPS), battery] retained by it. For universal applications, the transponder would be held in a retainer unit (see Figure 1) mounted on a cargo container. The retainer unit would be the medium through which information would be transferred. The retainer unit would function somewhat in the manner of a credit-card reader, except that the reading would be done completely electronically; that is, there would be no moving magnetic reader head because the information would not be stored in magnetic strips as it is on credit cards. The retainer unit would include an infrared transceiver for local communication and a microwave transceiver for communication over longer distances (see Figure 2).

There are many ways of transferring information to the transponder. Information on the cargo could be transferred into the transponder RAM from a laser bar-code scanner wired to the retainer unit by a long, flexible cord like a telephone cord. Alternatively, the information could be transmitted from a remote bar-code reader analogous to devices now used in rental-car-return yards. A third alternative would be to enter the data manually via a keyboard.

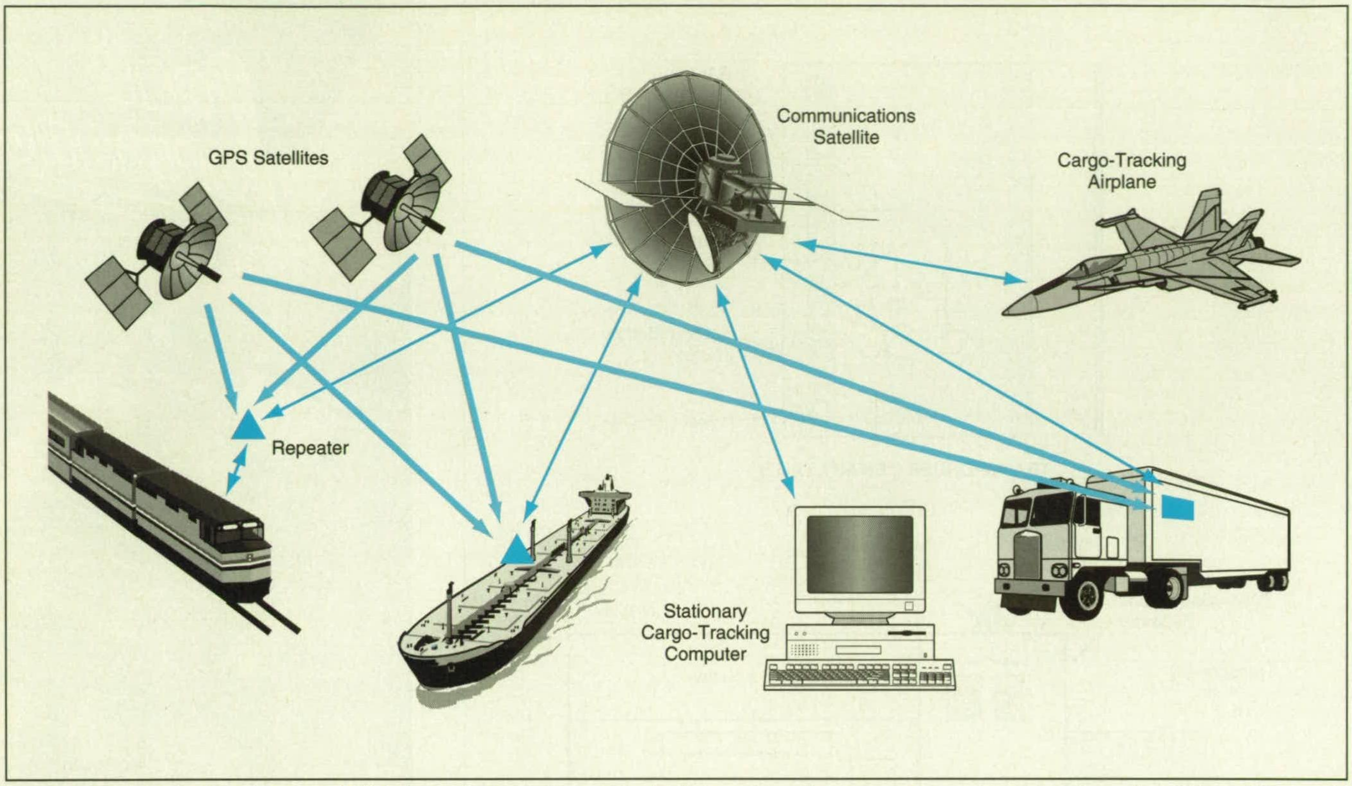


Figure 2. A **Network of Satellites** would link "smart" tags on transport vehicles over long distances to a central interrogation point. GPS satellites would send data to the tags about their current locations.

Either the transponder or the retainer unit would include a GPS receiver, with GPS being integral with the transponder when used alone. Periodically (e.g., every 15 minutes) data on the latitude and longitude of the unit, as determined from GPS signals, would automatically be stored in the transponder RAM.

To retrieve information from the transponder at short range (about 100 m or less), an operator would aim an infrared interrogation "gun" at the retainer unit. From somewhat greater distances, information could be retrieved through infrared or microwave repeaters in the transport vehicle, at shipping depots, or at stations en route, for example. At still greater distances, satellite microwave links would be used. Thus, data on the contents, ownership, origin, destination, and location of a cargo container could be obtained at any time from anywhere.

When the cargo reached its destination, the transponder would be removed from the retainer and inserted into a reader on a personal computer to obtain a complete shipping record. The transponder could be then filed or reused for subsequent shipments.

This work was done by Philip I. Moynihan and Govind K. Deshpande of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-19769.

Computer-Controlled Instrumentation Measures Hydrogen Leaks

Stennis Space Center, Mississippi

An instrumentation system monitors rates of leakage of hydrogen from multiple zones on a complexly shaped tank. Each zone is established by bagging a designated exterior portion of the tank. The bag for each zone is purged with a carrier gas (either nitrogen or helium) at a controlled flow rate, then the carrier gas with leaked hydrogen (if any) mixed in is routed to one of two mass spectrometers, which can measure concentrations of hydrogen from 30 parts per million to 4 percent calibrated. Microelectronic sensors are used to measure concentrations from 2.5 to 100 percent, enabling the hydrogen concentration to be determined after the mass spectrometers have reached their saturation point. Inlet valves on each mass spectrometer enable the selection of purge exhaust to be sampled from any of eight zones. The microelectronic sensors are positioned in the exhaust flow from the mass spectrometers. A computer, acting via a programmable-logic controller, monitors and controls valves, flow-control valves, and related instrumentation. Another computer monitors and controls the mass spectrometers. Hydrogen-concentration data acquired by the mass-spectrometer-control computer are fed to the flow-control computer, which computes hydrogen-leak rates from the measured hydrogen concentrations and flow rates. The microelectronic-sensor data are recorded by the facility Data Acquisition System.

This work was done by Glenn Varner of **Stennis Space Center** *and Phillip Hebert and Lester Langford of Lockheed Martin. For further information, access the Technical Support Package (TSP)* ***free on-line at*** *www.* ***nasatech.com*** *under the Physical Sciences category. SSC-00065*

Using CT Data in Finite-Element Models of MMC Components

Computer simulations based on nondestructive computed tomography could replace some costly experiments.

Lewis Research Center, Cleveland, Ohio

X-ray-based Computed Tomography (CT) has been linked with finite-element analysis to provide a capability for structural characterization of as-manufactured parts — especially for the nondestructive evaluation of metal-matrix composite (MMC) material parts. In some cases, this capability might eventually obviate costly experiments, including destructive experiments that are traditionally performed to determine mechanical responses. Though developed primarily for MMCs, this capability could also be applied to other types of composites, metal forgings and castings, and plastic components.

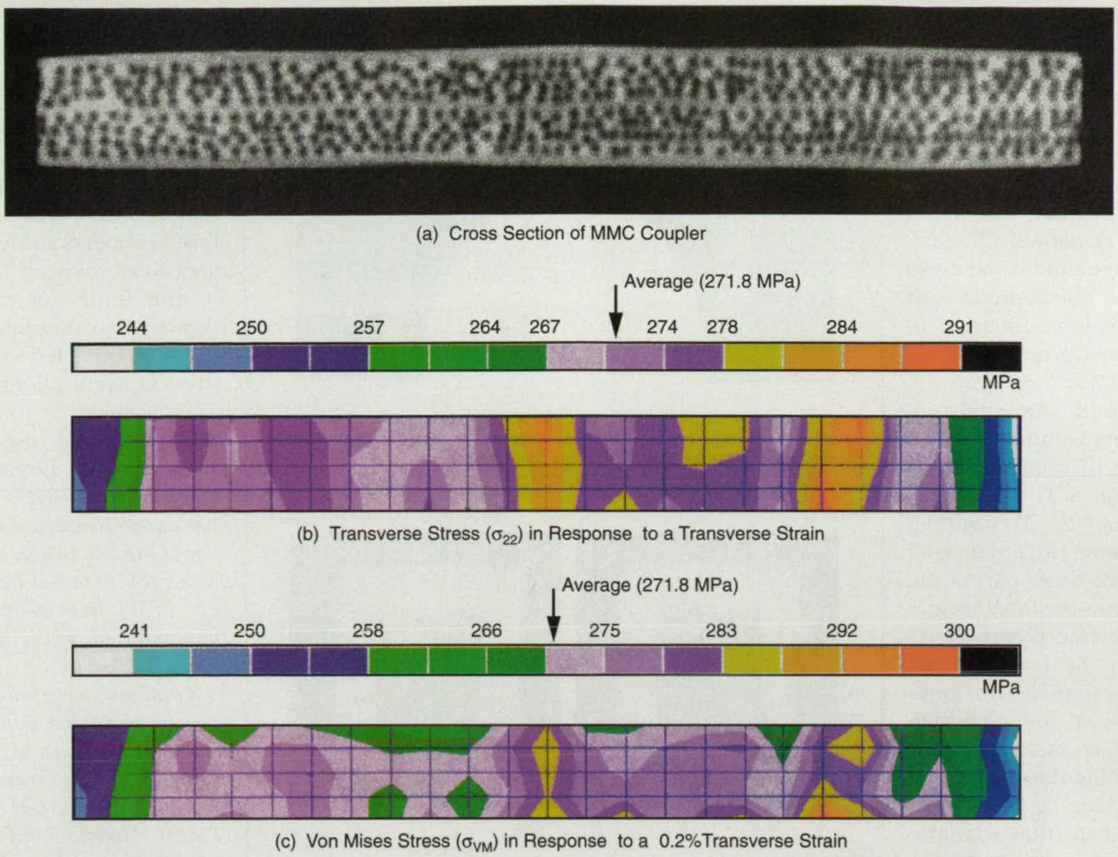


Figure 1. This **Cross Section of an Eight-Ply MMC Coupon** was made by CT with sufficient resolution to show individual fibers. Images like these can be digitized, then processed (1) by image-analysis software to obtain fiber volume fractions and (2) by applied load to obtain stress distribution as shown in (b) and (c).

The basic idea is to utilize data obtained nondestructively to eliminate the need for mechanical testing of a component. In the present approach, one does this by using a finite-element structural-analysis computer program to predict the behavior of the component under load (including, for example, effects of stress concentrations), in combination with information obtained nondestructively by x-ray CT of the component. In the program, local variations in material properties are approximated by differences among the material-property parameters of the finite elements. The values of the finite-element material parameters are, in turn, calculated from such data as local volume fractions of fibers as determined by analysis of CT imagery.

To link the CT and finite-element-analysis capabilities, it was necessary to develop software to overlay finite-element meshes on CT images, software to manipulate nodes of finite-element meshes to conform with geometries of tomographic slices, and software to classify and manage input and output data pertaining to each finite element. Two case studies were performed to demonstrate the resulting capability. The first study involved MMC test coupons like that of Figure 1. Image-processing tech-

niques were used to segment the fibers from the matrix, then there was created a finite-element mesh, wherein each finite element had unique stiffness properties based on the volume fraction of fibers in that element as calculated from the segmented CT data. The finite-element analysis showed that concentrations of high-fiber-volume-fraction finite elements produced stress concentrations.

The second case study involved a ring comprising (1) a core made of a composite of SiC fibers in a Ti matrix surrounded by (2) Ti cladding and including (3) a damaged area near the outer part of the core. CT cross-sectional images of the ring (see Figure 2) revealed that the core was not uniformly shaped or positioned within the cladding. Several CT cross-sectional images, including the ones in Figure 2, include a bright line across the core that was later determined to represent overlapping of a titanium foil. Variations in the density of the core as shown in the cross-sectional CT images were later correlated with variations in fiber volume fraction. In this study, a finite-element mesh was created to match the ring geometry, and the stiffness parameters in the finite elements in the damaged area were reduced. The results of the finite-element analysis showed that the damaged area could be expected to give rise to stress concentrations elsewhere in the ring.

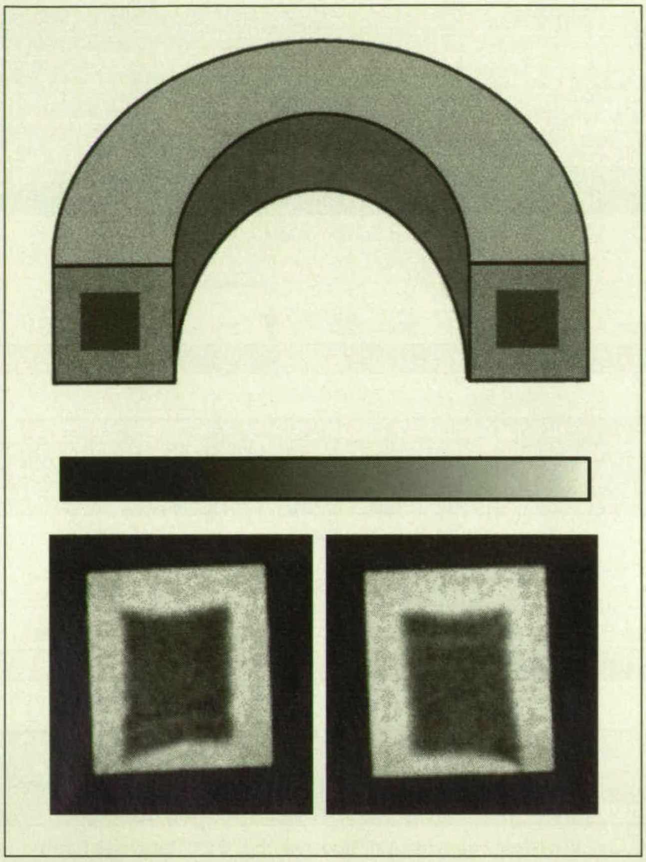


Figure 2. Two **Cross-Sectional CT Images of a Composite Ring** show imperfections of the Ti-matrix/SiC-fiber core and the Ti cladding.

This work was done by George Y. Baaklini of **Lewis Research Center** *and Robert N. Yancey of Advanced Research and Applications Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16618.

Work [sho

Special Coverage: Data Acquisition

The LogBook/300™ standalone **data acquisition system** from IOtech, Cleveland, OH, is a portable, PC-based system that can operate without an attached PC. The system contains an embedded 486 processor, and can execute programs and store acquired data using off-the-shelf removable PC-card memory. It combines 100-kHz sampling speed with more than 450 analog and digital channels.

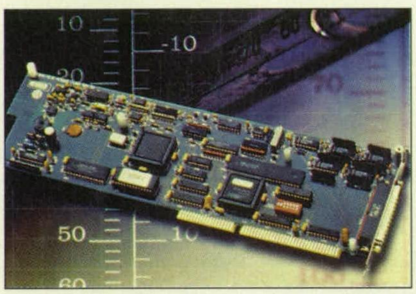
The basic system, which is smaller than a notebook PC, features a 16-bit, 100-4 frequency inputs; 2 pulse train outputs; and 4 optional 16-bit analog outputs. It stores data in the non-volatile memory of a standard Type I or Type II hard-drive PC-Card. A 500-Mb card can store up to 250 million samples. Also included is LogView™ Out-of-the-Box™ data acquisition and display software. Options include a remote operation terminal that connects to the system with a thin cable.

For More Information Circle No. 743

R.C. Electronics, Santa Barbara, CA, has released the DataMax® Test Friendly™ **data acquisition system** that features an analog bandwidth of 90 kHz. The instrument combines the functionality of an oscilloscope, a digital tape recorder, and a graphical playback unit into one system. The recorder is configured with a 9 Gb hard drive for 45 minutes of recordings on 16 channels at 40 kHz. The DataMax Interface provides one-button, auto-set, instant signal capture that displays any input signal regardless of the amplifier or gain setting.

The system's chassis incorporates shock-mounted drive bays, high-capacity fans, and positive hold mechanical restraints in a shock-resistant housing. A programmable differential amplifier accepts signals of wide dynamic range and high frequency, permitting static, vibration, acoustic, sonar, and pyroshock tests. An individual analog-to-digital converter is included for each channel.

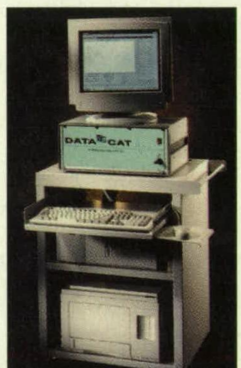
For More Information Circle No. 747



Keithley Instruments, Cleveland, OH, offers the DAS-TC/B PC plug-in **data acquisition board** for thermocouple and voltage inputs. It can accept any mix of seven different types of thermocouple, millivolt, and voltage signals over 16 differential inputs without the need for external signal conditioning. The board provides measurements at up to 100 samples per second.

A voltage-to-frequency converter facilitates stable thermocouple readings in noisy environments. An onboard processor provides automatic calibration, gain selection, CJC, thermocouple linearization, conversion to degrees or volts, and averaging. It can be operated under Windows 95, and comes with a Windows-executable, menu-driven DataLogger utility that enables users to test applications, monitor inputs, and store data to disk without programming.

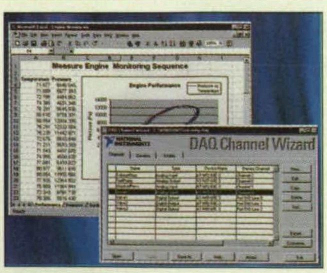
For More Information Circle No. 742



Carleton Technologies, Orchard Park, NY, offers the DATA CAT **data acquisition and control system** that consists of the DATA CAT interface box, a 200-MHz Pentium computer with 17" monitor, and Windows-based data acquisition software. The system provides up to 16 analog input channels, dual sample rates to 100K samples/second, two analog output channels, eight control relays, and three power supplies. The software requires no programming and guides users through test set-up.

The system displays real-time data while testing, and allows post-test data analysis and manipulation for tabular and graphical presentation. The system also features a high-end 16-bit DAC board, and is available with an optional cart and printer. Temperature, flow, pressure, resistance, voltage, current, velocity, force, acceleration, frequency, distance, power, and strain data can be acquired and stored.

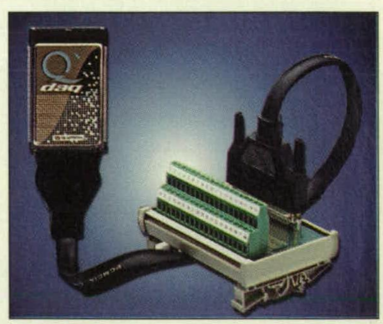
For More Information Circle No. 746



National Instruments, Austin, TX, offers a new version of its Measure **data acquisition and instrument control software** using Microsoft Excel on Windows 95/NT PCs. The software features dialogs for setting up acquisition and control operations, allowing users to configure and control data acquisition hardware as well as serial or GPIB instruments. Acquisition results can be dropped directly into spreadsheet cells for analysis and graphing.

The supported DAQ Channel Wizard reduces time spent defining signal types, connections, and transducer equations before beginning system development. A user fills in dialog windows to define an input signal, the type of transducer, scaling factors required, CJC values, and unit conversion factors. They then reference the channel name for the input signal in Excel, and the conversion processes are performed transparently.

For More Information Circle No. 751



Quatech, Akron, OH, has announced the DAQP-12H **data acquisition adapter** that provides 12-bit resolution for eight differential or 16 single-ended analog input channels, sampling rates to 100 kHz, and eight digital I/O channels. Programmable gains allow the unit to be configured for ±10V, ±1V, ±100mV, and ±10mV input ranges. It is equipped with a 2K data FIFO for Windows 95, and has a 2048 entry scan FIFO that supports random order channel scanning and gain selection.

The adapter includes the company's DAQDRIVE® universal software driver, which supports programming languages such as Microsoft C/C++, QuickBasic, and Turbo Pascal. Also included is DaqEZ™, a Windows-based data acquisition application software package that enables advanced graphic and monitoring functions.

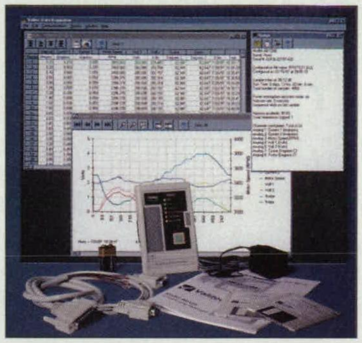
For More Information Circle No. 744

Special Coverage: Data Acquisition

DATAQ Instruments, Akron, OH, has introduced the DI-720 and DI-730 portable **data acquisition systems** that communicate with a PC's printer port in EPP, bi-directional, or Standard mode. The DI-730 features a measurement range of ±10mV to ±800VDC across six ranges per channel, with ±1000V channel-to-channel isolation. It offers eight differential channels at sampling speeds of 250 kHz at 16-bit resolution.

The units provide an Ethernet 10BaseT communication port option for connection to any local or wide area network that supports the TCP/IP protocol for Windows 95/98/NT. Both units also come with acquisition and playback software. The DI-720 offers up to 32 single-ended or 16 differential analog input channels at sampling speeds to 250 kHz at 16-bit resolution. Both models are DSP-based, have built-in pre- and post-triggering, and support average, maximum, minimum, and last-point acquisition methods.

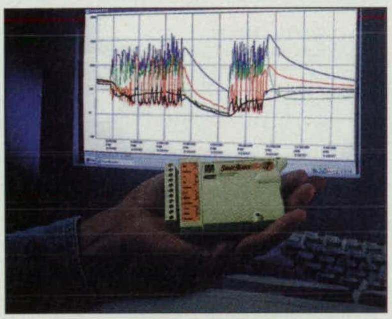
For More Information Circle No. 740



The AD128 ReadyTec™ pocket-sized **data acquisition system** from Valitec, Dayton, OH, is a standalone system that features maximum sampling speed of 100 Hz and has a 4,000 sample storage capacity. Information can be recorded over periods of seconds to years. The system includes the ReadyTec logging unit, Configuration & Analysis Software V4.0, and accessories such as a 9-pin RS-232 communication cable, sampling interface cable, AC wall adapter, and 9V battery.

Other features include trigger or event-based recording, input scaling, presentation-quality data plots, and data statistics. Users can view maximum, minimum, average, or standard deviations in numerical and graphical form for each input channel. All readings are stamped with the date and time.

For More Information Circle No. 745



The SmartReader Plus Model 7 standalone, pocket-sized **data logger** from ACR Systems, Surrey, BC, Canada, has one internal temperature channel and seven analog inputs. The unit includes appropriate transducers connected to it for measurement and recording of relative humidity, pressure, current, flow, voltage, vibration, tank levels, torque, and acceleration.

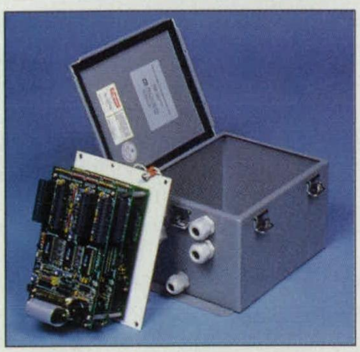
The logger can store 87,000 readings and is equipped with a 10-year battery. The logger can be placed at a remote site, and via modem, the settings can be changed or data can be downloaded. Logged data can be retrieved to any PC and displayed graphically and statistically with the company's Windows-based software or other spreadsheet. A dialout feature enables the system to dial from a remote location to notify the operator of an alarm condition.

For More Information Circle No. 750

The PC-414K dual-channel, high-speed analog input **data acquisition board** from Datel, Mansfield, MA, is designed for ISA bus-compatible computers, and features input bandwidth up to 2.5 MHz with simultaneous sampling of each channel at a rate up to 5 MHz. Full-scale input ranges are from 0 to +10V or ±5V. The simultaneous sampling section acquires signals on parallel channels at the same time, preventing phase errors and skewing of multichannel correlated signals.

The board features 12-bit A/D resolution, non-bus burst parallel port for seamless recording, on-board FIFO memory that holds 16,384 samples, and software compatible with Pentium® and Windows 95/NT. The board provides five SMA coaxial signal connectors — four for the sampled analog channels, and a fifth connector for external timebase clock input, external analog trigger signal, or for the analog output.

For More Information Circle No. 741



Acces I/O Products, San Diego, CA, has introduced RIDACS, a remote intelligent **data acquisition and control system** that allows users to install a variety of interfaces and control outputs close to the sensors and controllers, and to communicate with a host computer via a two-wire, high-noise-immunity serial communications network. Remote communications up to 4,000 feet between the system pods and a host computer with an RS-485 port are possible.

The system includes either a 4" or 6" depth NEMA4 enclosure containing one RAG128 remote access pod, and a choice of single or dual AIM-16P signal conditioning multiplexers with 16 channels each, single or dual eight-channel LVDT-8 multiplexer/signal conditioners, and all interconnecting cables.

For More Information Circle No. 749

The PortaScan LT **ultrasonic data acquisition system** from NDT Systems, Huntington Beach, CA, incorporates a standard IBM-compatible notebook computer and a high-speed PC card (PCMCIA) digitizer to collect and display A-scan, B-scan, C-scan, D-scan (TOFD), and stacked A-scan (TOP) data. The system acquires data for ultrasonic corrosion mapping, flaw detection, and angle beam inspection. Manual and automated scanners are available.

Display software links the entire range of map types to provide analysis of inspection data. Its pulser/receiver achieves 90 dB of dynamic range and a 40-MHz, 9-bit digitizer captures full waveform. The system's acquisition software is Windows compatible.

For More Information Circle No. 748

Optoelectronic Generation of Optical and Microwave Signals

Optical and electrical oscillations are coupled to each other.

NASA's Jet Propulsion Laboratory, Pasadena, California

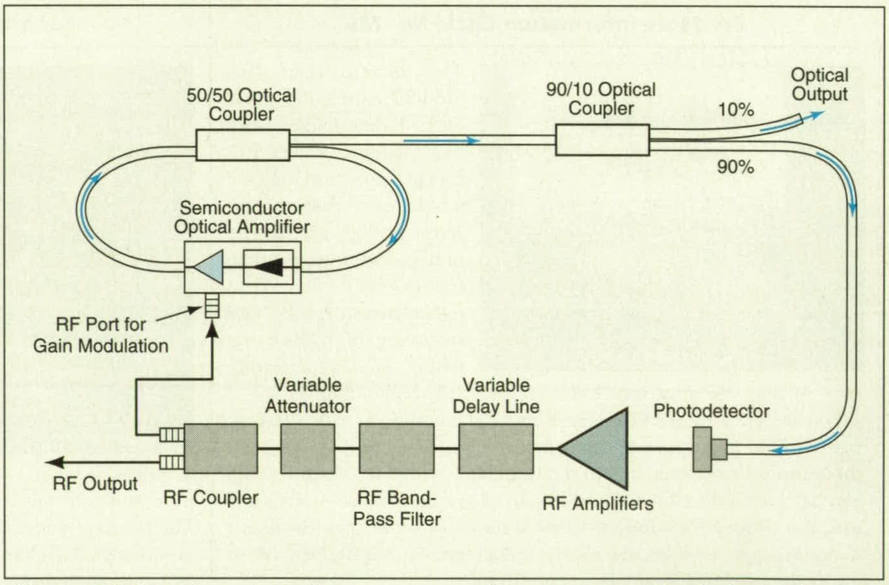
The figure schematically illustrates an optoelectronic apparatus that generates both an optical output and an electronic output (typically at frequencies in the range from hundreds of megahertz to tens of gigahertz). The apparatus is denoted a "coupled optoelectronic oscillator" (COEO) because its optical and electronic oscillations are coupled to each other.

The COEO is the latest product of a continuing effort to develop photonic/electronic frequency synthesizers with low phase noise, wide tuning range, and high resolution in frequency. Previous developments in this effort were described in a number of articles in *NASA Tech Briefs*, including "Light Induced Microwave Oscillator" (NPO-19440), Vol. 20, No. 9 (September 1996), page 4a; "Electro-Optical Clock- and Carrier-Recovery Device" (NPO-19573), Vol. 20, No. 9 (September 1996), page 6a; and "Self-Injection-Locked Electro-Optical Microwave Oscillator" (NPO-19568), Vol. 20, No. 8 (August 1996), page 17a.

The COEO is based partly on concepts described in yet another prior *NASA Tech Briefs* article; namely, "Multiloop Photonic/Electronic Frequency Synthesizers" (NPO-19825), Vol. 21, No. 6 (June 1997), page 10a. To recapitulate: A rudimentary but impractical photonic/electronic oscillator would include a single optical feedback concatenated with an electrical feedback loop. By including a radio-frequency (RF) filter with narrow pass band in the electrical feedback loop, one could allow oscillations to occur in one electromagnetic mode while suppressing oscillations in other modes. To reduce phase noise, the length of the optical feedback loop must be increased; this would reduce the frequency interval between modes, necessitating a reduction in the bandwidth of the RF filter to ensure the selection of only the desired modal frequency. However, at a typical frequency that one seeks to generate (of the order of 10 GHz), it is difficult to make an RF filter with pass band narrow enough to discriminate between modes. In addition, the inclusion of a narrow-band RF filter would sacrifice the tunability of the oscillator.

A multiple-loop apparatus could satisfy the need for both a longer optical feedback loop to reduce phase noise and a shorter optical feedback loop to facilitate discrimination against unwanted modes without need for a narrow-band RF filter, while providing broad frequency tunability. The multiple-loop apparatus proposed in the cited prior article would include a pump laser, a longer and a shorter fiber-optic delay line (longer and shorter optical feedback loops), a photodiode followed by an amplifier at the output end of each optical fiber, and a dual-drive electro-optical modulator that would be common to both fiber-optic delay lines and would be driven by the outputs of the amplifiers.

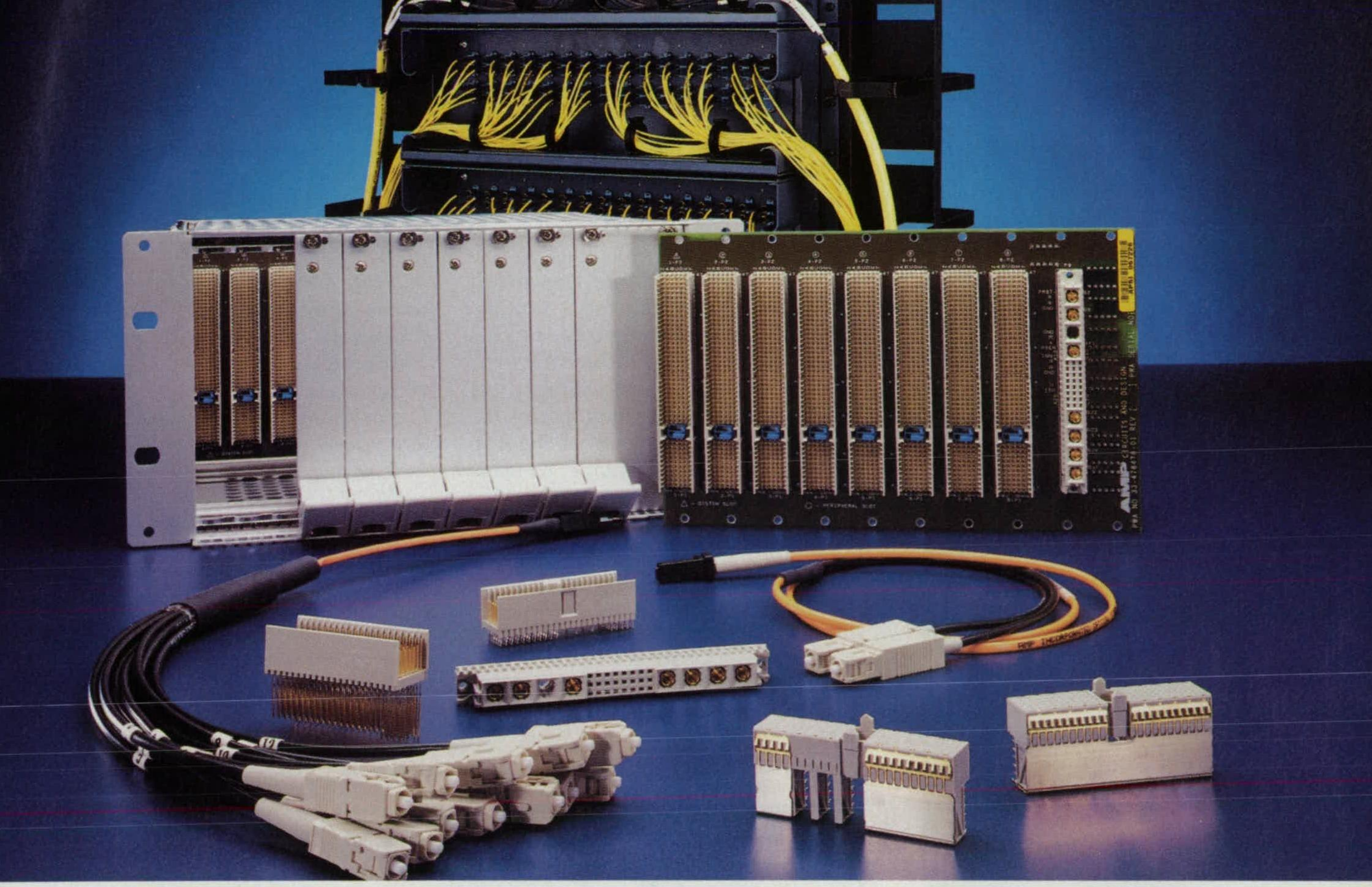
The COEO is a multiple-loop photonic/electronic oscillator, but it differs from the apparatus of the cited prior article in some important ways. Here, one does not use an external laser to pump the optoelectronic feedback loops; instead, the laser is an integral part of both the shorter feedback loop and of a semiconductor optical amplifier (SOA), the gain of which can be modulated electrically. The laser is a ring laser, so that its optical cavity (the ring) constitutes the shorter optical feedback loop. The laser has many longitudinal modes at integer multiples of a frequency interval that depends on the length of the loop. A typical value is 23.3 MHz, corresponding to a loop length of 8.58 m. The longitudinal modes of the longer loop are separated by much smaller frequency intervals.



This **Coupled Opto-Electronic Oscillator** generates stable microwave and pulsed optical outputs simultaneously.

A 50/50 optical coupler draws optical power from the shorter optical feedback loop, and a subsequent 90/10 optical coupler feeds optical power into the longer optical feedback loop. At other end of the longer loop, the optical signal is fed to a photodetector. The electronic output of the photodetector is amplified, delayed, band-pass-filtered, and attenuated as needed, and some of the resulting RF signal is fed to the modulator port of the SOA.

The midband frequency of the band-pass filter is chosen to be an integer multiple of the frequency interval between laser modes, and the bandwidth



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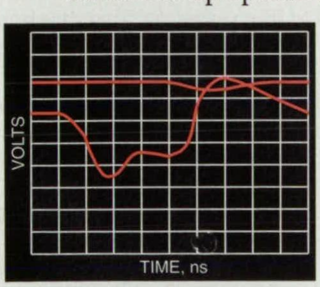

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is chosen to be less than this interval, so that the band-pass filter effectively picks out one of the beat frequencies between modes. Without the RF feedback to the SOA, the phases of the longitudinal modes of the ring laser would be independent of each other, so that the optical output would be nearly steady, with superimposed random power fluctuations caused by interference among the modes. However, in the presence of the band-pass-filtered RF feedback at an integer multiple of the laser modal frequency interval, the sidebands of the modulated modes coincide with the frequencies of other modes, so that all the modes become injection-locked by the RF feedback. Many modes of the longer feedback loop compete to oscillate within the pass band, and the winner is the one with a frequency closest to the beat frequency, because only this one can mode-lock the ring laser. The superposition of locked modes causes the optical output to consist mostly of a train of pulses.

This work was done by Xiaotian Steve Yao and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

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Refer to NPO-20090, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fabrication of Thinned QWIP Arrays for Improved Performance

Dark current and crosstalk would be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

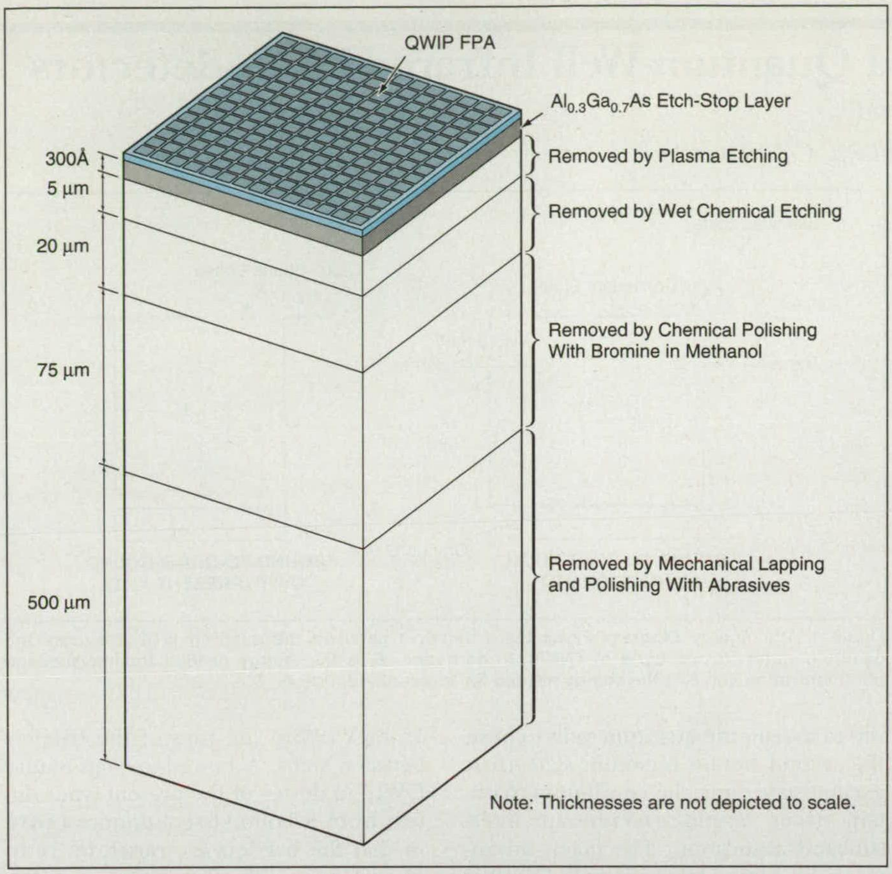
Focal-plane-array (FPA) hybrids of quantum-well infrared photodetectors (QWIPs) thinned to the membrane level are undergoing development. The developmental QWIPs in question are of the kind that exploit bound-to-quasi-bound absorption, as described, for example, in "Bound-to-Quasi-Bound Quantum-Well Infrared Photodetectors," which immediately follows this article. The present development encompasses both the thinned-array design and the method of fabrication.

Unthinned and partially thinned QWIP FPA hybrids developed previously have been characterized by crosstalk among pixels, thermal mismatches between the FPA hybrids and associated readout multiplexers, and poor light-coupling efficiency. The developmental thinned QWIP FPAs overcome these deficiencies and offer other improvements in performance, as follows:

- The thermal masses of FPAs are so small that they adapt the thermal expansion and contraction coefficients of Si CMOS (complementary metal oxide/semiconductor) readout multiplexers.
- The more favorable aspect ratios created by thinning maximize the efficiency of coupling of light from random reflectors.
- Crosstalk among pixels is suppressed because after thinning, the remaining substrate thickness is too small to support appreciable crosstalk.

A QWIP FPA of the present type is fabricated on top of a 300-Å-thick layer of $Al_{0.3}Ga_{0.7}As$ that, in turn, has been deposited on a relatively thick (several hundred μm) GaAs substrate. Then the thinned QWIP FPA is formed by removing the substrate from under the $Al_{0.3}Ga_{0.7}As$ layer in the following sequence of processes:

1. Formation of a QWIP FPA hybrid via indium bump-bonding process. This hybrid consists of QWIP FPA and Si CMOS readout multiplexer.
2. The hybrid is backfilled with low-viscosity epoxy.
3. By mechanical lapping and polishing with abrasives, most of the thickness is removed from the bottom side, leaving a substrate thickness of 100 μm.
4. Chemical polishing with a solution of 1 part bromine and 100 parts methanol is used to remove the next 75 μm.
5. The next 20 μm of thickness is removed in an 8-minute wet-chemical etch with a solution of 5 parts H_2SO_4, 40 parts H_2O_2, and 100 parts H_2O.



The **GaAs Substrate** supports the QWIP FPA during initial fabrication. The substrate is removed by a sequence of processes, leaving only the QWIP FPA on the etch-stop layer.

6. The remaining 5 µm of substrate thickness is removed by dry etching in a plasma formed from CCl_2F_2 gas. The $Al_{0.3}Ga_{0.7}As$ layer acts as an etch-stop layer during this process, in that the plasma etches the GaAs substrate material much faster than it etches $Al_{0.3}Ga_{0.7}As$.
7. An O_2 plasma is used to remove a grayish film that remains after the CCl_2F_2 plasma etch.

This work was done by Sarath Gunapala, John K. Liu, and Mani Sundaram of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www. nasatech.com*** *under the Electronic Components and Circuits category.*

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Bound-to-Quasi-Bound Quantum-Well Infrared Photodetectors

Dark current is reduced substantially.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multiple-quantum-well $Al_xGa_{1-x}As$ photodetectors that exploit transitions of electrons from quantum-well bound states to quasi-bound states are undergoing development for use at wavelengths from 6 to 25 μm. These photodetectors are intended to provide detectivities that are higher (signal-to-noise ratios that are higher) than those of predecessor quantum-well infrared photodetectors that exploit transitions of electrons from bound to continuum states.

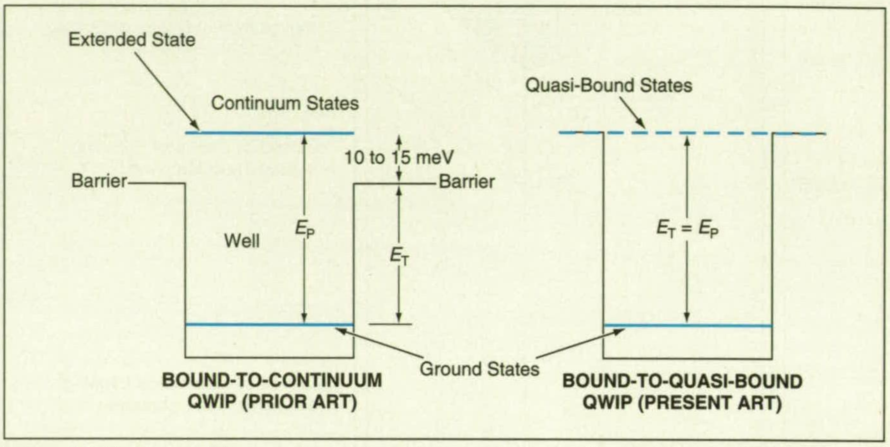

Figure 1. This **Energy Diagram** shows the differences between the quantum-well structures and quantum states in two types of QWIPs. In each case, E_P is the energy needed for intersubband photoionization and E_T is the energy needed for thermionic emission.

Noise in a photodetector is associated with dark current — a component of current that flows whether or not illumination is present. The three mechanisms that contribute to dark current in a multiple-quantum-well photodetector are (1) temperature-independent quantum-mechanical sequential tunneling through the barriers between the wells, (2) thermally assisted quantum-mechanical tunneling through the last barrier into continuum states, and (3) classical thermionic emission. The problem, then, is to maximize the photocurrent/dark-current ratio; this must be done by tailoring (a) the depth of the wells (by suitable choice of the composition parameter x in the well and barrier layers) and (b) widths of the wells and barriers (by suitable choice of the thicknesses of the well and barrier layers) to obtain a multiple-quantum-well structure that is optimum for the purpose.

In the development of the predecessor quantum-well infrared photodetectors (QWIPs), a large part of the strategy was to narrow the quantum wells to push the second bound quantum state (first excited state) into the continuum to obtain strong bound-to-continuum intersubband absorption. The major advantage of a bound-to-continuum QWIP is that a photoexcited electron can escape from a quantum well to the continuum transport states without having to tunnel through a barrier (see Figure 1). As a result, the bias needed to collect photoelectrons efficiently can be reduced from the bias needed to collect photoelectrons via quantum tunneling as in some prior photodetectors, thereby decreasing the component of dark current attributable to sequential quantum tunneling. Moreover, because the photoelectrons do not have to tunnel through the barriers, the barriers can be thickened to reduce ground-state sequential tunneling to effect a further decrease in dark current.

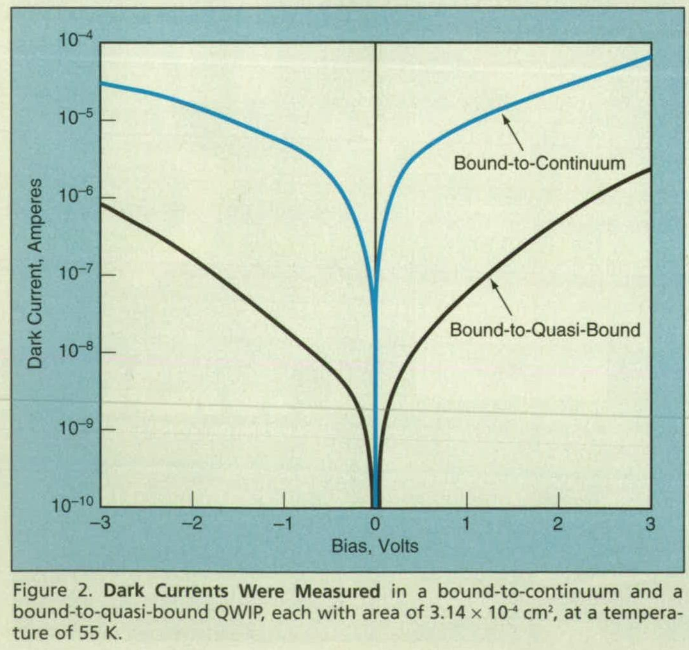

Figure 2. **Dark Currents Were Measured** in a bound-to-continuum and a bound-to-quasi-bound QWIP, each with area of 3.14×10^{-4} cm², at a temperature of 55 K.

In a bound-to-continuum QWIP, the energy barrier, E_T, for thermionic emission is about 10 to 15 meV less than the energy, E_P, needed for intersubband photoionization; that is, the extended state (or virtual level) lies 10 to 15 meV above the tops of the barriers between wells. A bound-to-quasi-bound QWIP (a device of the present type) differs from a bound-to-continuum QWIP in that the barriers are raised by 10 to 15 meV so that the first excited state lies at the tops of the barriers. The additional barrier height reduces thermionic emission over the barriers, thereby reducing the dark current. In addition, the bound-to-quasi-bound transition maximizes intersubband absorption while maintaining excellent electron transport.

As shown in Figure 2, the dark current in an experimental bound-to-quasi-bound QWIP was found to be about 1/12 that of a comparable bound-to-continuum QWIP. As a result, the signal-to-noise ratio of the bound-to-quasi-bound device is about 3.5 times that of the bound-to-continuum device.

This work was done by Sarath D. Gunapala, Jin S. Park, Gabby Sarusi, and John K. Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

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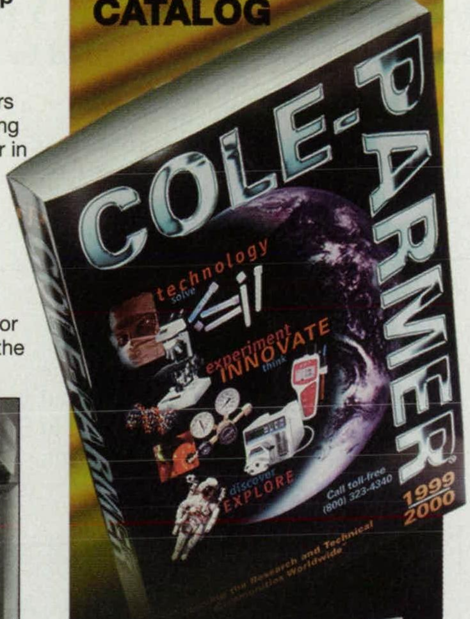

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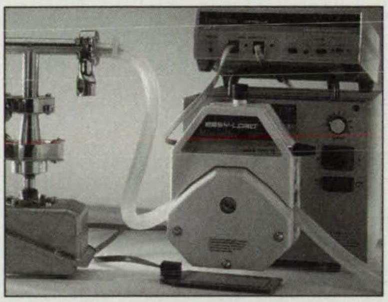

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Engine Monitoring Based on Normalized Vibration Spectra

Spectra are normalized in frequency and phase, then classified by a neural network.

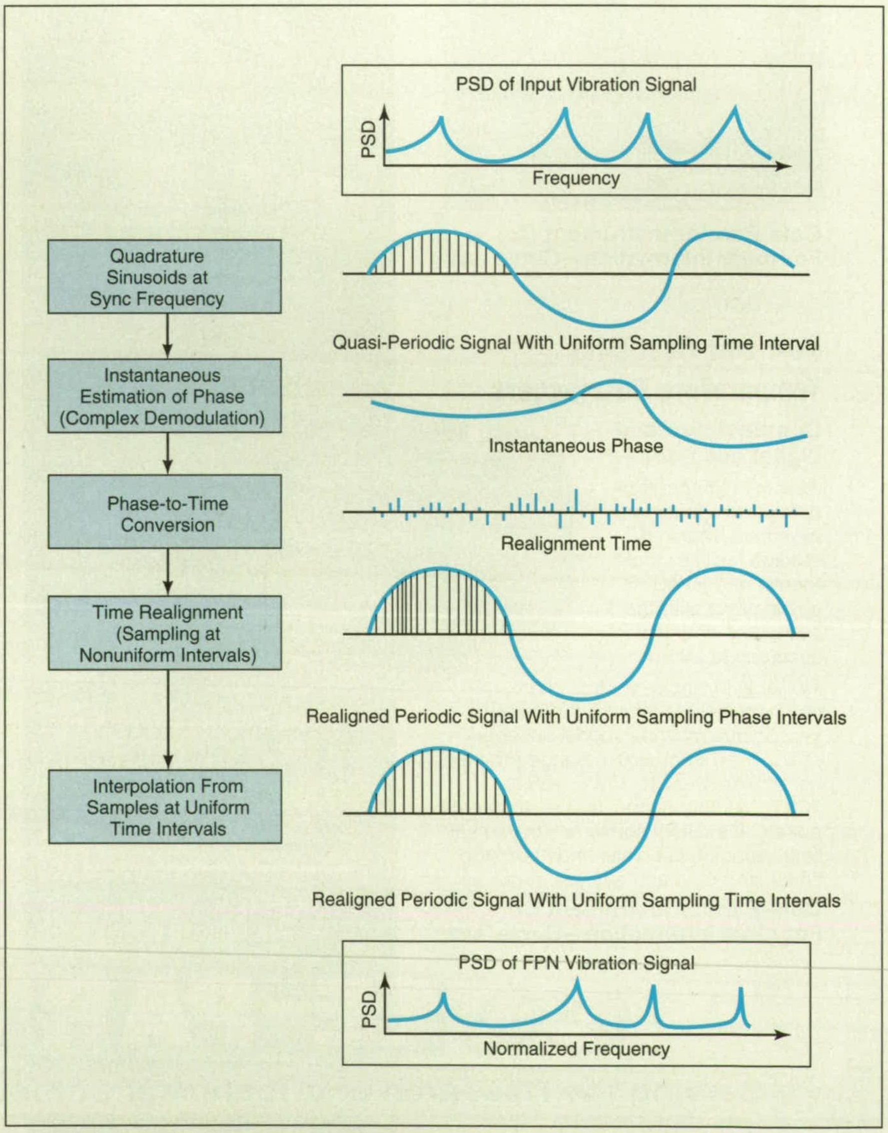
Marshall Space Flight Center, Alabama

An electronic engine-health-monitoring system is based on (1) computation of frequency-phase-normalized (FPN) spectra from the digitized outputs of vibration sensors and (2) the use of these spectra as feature vectors, which are presented to an artificial neural network for recognition of features associated with incipient failures. The normalization in question is with respect to the instantaneous frequency and phase of rotation of the engine shaft [customarily denoted the "sync" (short for "synchronous") frequency and phase, respectively]. FPN spectra are useful for extracting that dynamical information that is most useful for detection and classification of failures.

Most machinery failures are preceded by growing tolerances, imbalances, and bearing-element wear, which give rise to subtle modifications of vibration waveforms. The vibration waveforms, and thus the subtle waveform modifications, are corrupted by such benign phenomena as environmental noise, fluid/structural interactions, nonlinear coupling, and feedthrough of vibrations from nearby machinery, all of which compound the diagnostic task. An important element of a vibration-based engine-monitoring system is the ability to extract true defect "signatures" from vibration-sensor outputs that also contain signatures of benign phenomena.

Other, similar systems have utilized frequency normalization; in particular, scaling of the frequency variables of conventional power spectral densities (PSDs) to sync frequencies, to provide more robust representations and simplify analyses of sync-related spectral components. However, the frequency-normalization processes in most such systems discard information on the relative phases of spectral components at various frequencies. These phase relationships are well hidden (they cannot be identified from conventional PSDs). They arise from nonlinear interactions among mechanical components; often, such nonlinear interactions are caused by mechanical defects. In the present system, the relative-phase information is preserved in the frequency-normalization process and is utilized to extract additional information about defects.

The raw vibration-sensor output is sampled and processed according to the phase-synchronized enhancement method (PSEM) (see figure). In this method, the quasi-periodic vibration signal is first sampled at constant time intervals. The sync component of the signal is assumed be characterized by small fluctuations in frequency and phase about a constant, pure sync tone; the instantaneous sync frequency and phase fluctuations are obtained by applying a demodulation technique to quadrature sinusoid representations of the sync signal. The estimated phase fluctuations are converted to time fluctuations (realignment time) to obtain slightly nonuniform time intervals for resampling the vibration signal at uniform phase intervals. The uniform-phase samples are equivalent to uniform-time samples of constant-fre-



The **PSEM Algorithm** converts a quasi-periodic signal to a periodic signal in which sync-related components are at discrete frequencies.

quency sync and sync-related components. Once the sync frequency component becomes discrete in the resampled signal, all other sync-related components automatically become discrete.

The phase relationships of interest are those between the sync signal and its harmonics. These relationships can be quantified by use of a hyperspectrum that comprises a hierarchy of joint moments between a reference spectral component (in this case, the sync component) and each of the harmonics. A hyperspectrum can be computed by use of fast Fourier transforms of signals that have been preprocessed by the PSEM.

The performance of the system has been studied in an application to vibration measurements from a bearing test rig, in an effort to identify spectral signatures that could be correlated with wear marks on ball bearings. The results of the study thus far indicate that the inclusion of phase information in FPN spectra yields signatures that enable discrimination of subtle changes that are not represented by spectral energy density or amplitude alone. As a result, a neural network can provide a more reliable and robust representation and classification of patterns for autonomous engine-health monitoring.

This work was done by Jong Jen-Yi of AI Signal Research, Inc., for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP) free on-line at www.nasatech.com under the Electronic Systems category. MFS-26529*

Parallel-Processing CDMA Detector With Neural Network

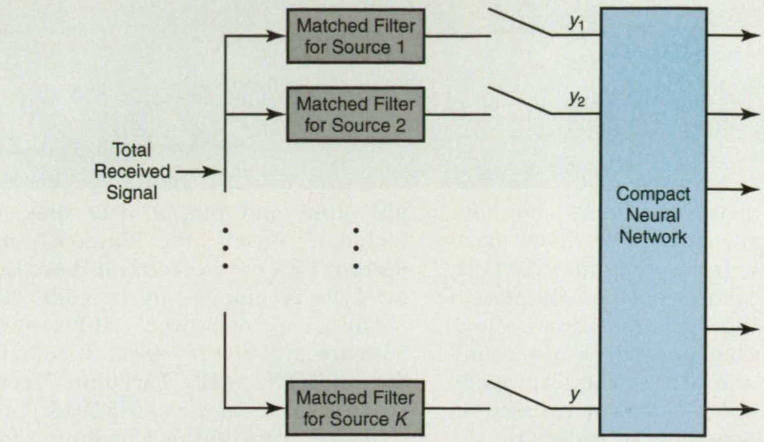
Near/far resistance is achieved by solving an optimization problem.

NASA's Jet Propulsion Laboratory, Pasadena, California

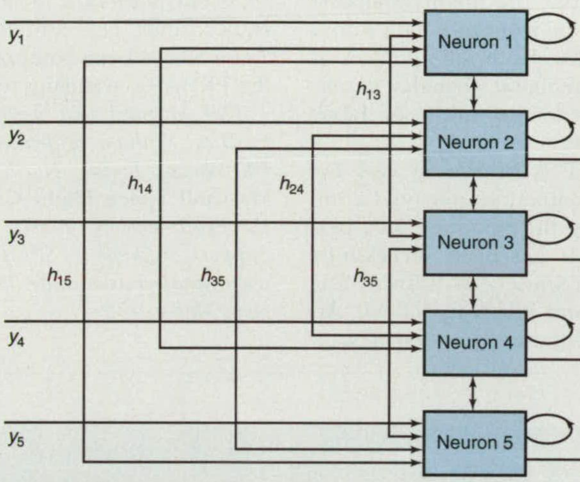
A proposed improved code-division multiple-access (CDMA) detector would achieve high resistance to jamming of weak ("far") received signals by strong ("near") ones. The problem of such jamming is called the "near/far problem," and resistance to such jamming is called "near/far resistance." The near/far problem is a major technical obstacle in the operation of CDMA radio-communication systems; for example, a system in which a base station must communicate simultaneously with near and far mobile units.

In a CDMA system, the binary signal from each source is multiplied, before transmission, by a distinct pseudonoise-code or other signature waveform. In a conventional CDMA detector, the signal received from each of K sources is isolated from the other K–1 signals by use of one of K matched filters that function in parallel. In each matched filter, the total received signal is multiplied by the signature waveform for the source in question, and the resulting product is integrated in time over a symbol period. A simple decision device then chooses the received bit (+1 or –1) on the basis of the sign of the output of the matched filter.

The point of departure for the design of the improved CDMA detector was the observation that the near/far resistance of a CDMA detector could be maximized (in the sense that the probability of error in detected bits could be minimized) by minimizing a quadratic objective function. Given a tentative decision as to the signals received from the various sources and as to the bits that the signals represent during a symbol pe-



IMPROVED CDMA DETECTOR



NEURAL-NETWORK ARCHITECTURE FOR EXAMPLE OF $K = 5$

A **Compact Neural Network** would process the outputs of matched filters in such a way as to obtain an optimal solution to the near/far problem.

riod, one suitable quadratic function is equivalent to an estimate of noise energy in the received signal.

The problem of minimizing an objective function amounts to an optimization problem. Thus, the near/far problem in CDMA reception can be converted to an optimization problem. A CDMA detector that achieves near/far resistance by solving this optimization problem is called an "optimal multiuser detector" (OMD).

In the improved CDMA detector, the outputs of the matched filters would be fed to a parallel-processing, compact neural network (see figure) in which the synaptic weights would be based on the $K \times K$ matrix of cross-correlations of signature waveforms. The neural network would implement a gradient-descent algorithm in an effort to minimize an energy function that would be modified by addition of a constraint energy. A simulated-annealing technique called "hardware annealing" would be employed to escape from local minima of the energy function. In the particular type of hardware annealing contemplated for this detector, the gain of each neuron would be continuously increased from a minimum to a maximum value. The combination of the constraint energy and the hardware annealing could significantly improve detection performance. A prototype very-large-scale integrated (VLSI) circuit version of the detector has been designed.

This work was done by Wai-Chi Fang of Caltech and Bing J. Sheu and Theodore W. Berger of USC for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

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Software

Simulation by Logical Modeling of Costs

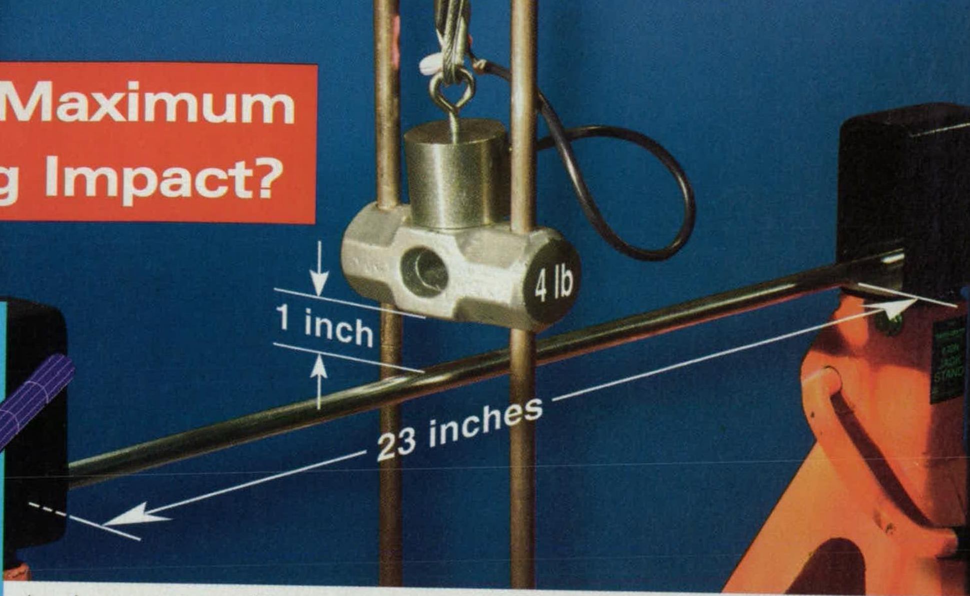
The Simulation by Logical Modeling of Costs (SIBYL/COST) software subsystem is used by logistical and financial analysts to develop cost projections of labor and hardware requirements for preparation of space shuttle main engine (SSME) spares proposals, SSME program operating plans (POPs), and special engine-cost studies. SIBYL/ COST makes projections of program resource requirements, identifies potential program threats and associated costs, evaluates adjustments of scope to meet funding levels, supports decision packages for pre- and post-POP exercises, and provides sufficient detail to support operating plans, team budgets, and changes in contracts for subsequent years.

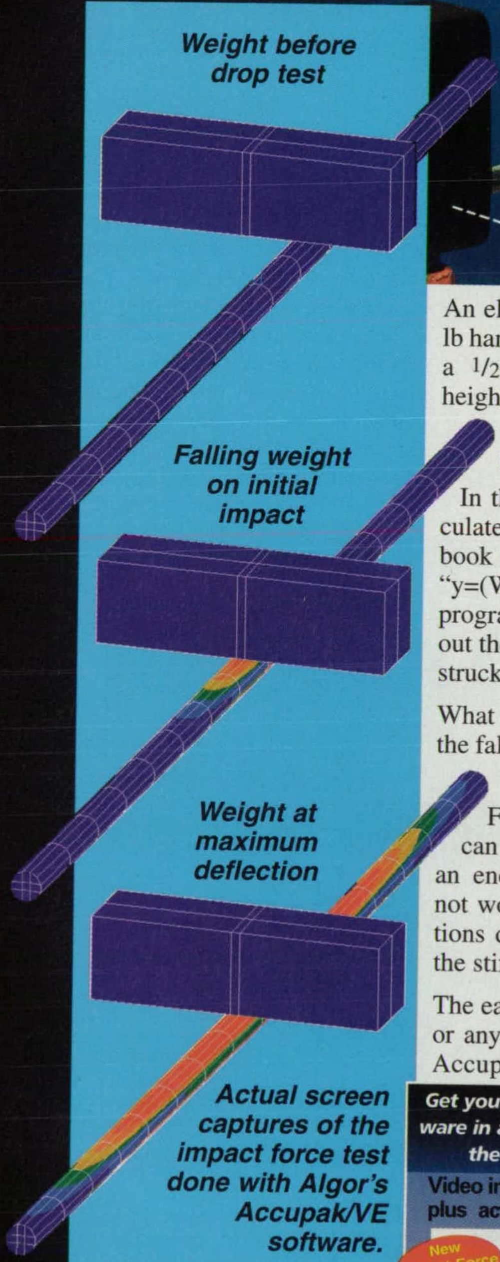
Pricing, financial, and logistical analysts and team members use SIBYL/ COST to make multiyear labor-hour and cost projections. The analyst starts the program by opening a new data file, which provides default component names, configurations, hardware schedule, and such tables as those of accounting hours and ogives. The team members then enter discrete data based on hardware schedule provided by the financial analyst. As each team's data become available, the financial analyst imports the team's discrete data into a central data file. Upon completion of this process, the financial analyst generates a multiyear projection of labor hours and costs.

SIBYL/COST is written in C++ for use on IBM-compatible personal computers running the Windows 3.1 operating system. It has been successfully implemented under Windows 3.1, Windows 95, and Windows NT 4.0. An executable program, together with sample input and output data files, is included. Btrieve for Windows and Spread/VBX are necessary if there is a need to recompile source code. To obtain a copy of Btrieve, call Pervasive Software at 1-800-287-4383. To obtain Spread/VBX, call FarPoint Technologies, Inc., at 1-800-645-5913. The standard distribution medium for SIBYL/COST is a set of three 3.5-in. (8.89-cm), 1.44MB diskettes in MD-DOS format. The contents of diskettes 2 and 3 have been compressed by use of the PKWARE archiving software tools.

This program was written by John K. Fredrick, William R. Jennings, and Hyon Ok Wu of Boeing North American for **Marshall Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category. MFS-30139*

What is the Maximum Force During Impact?



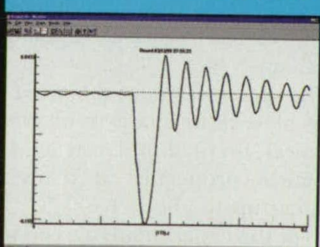


Weight before drop test

Falling weight on initial impact

Weight at maximum deflection

Actual screen captures of the impact force test done with Algor's Accupak/VE software.



Monitor program showing bar deflection vs. time.

An electromagnet suddenly releases a 4-lb hammer head weight which drops onto a 1/2-inch diameter steel bar from a height of 1 inch as shown above. The bar is 23 inches long between the supports.

In the past engineers would try to calculate the maximum stress using handbook calculations such as "s=Mc/I" and "y=(WL3)/(48EI)" or a linear static FEA program — but they would have to figure out the force applied to the bar when it is struck by the falling weight.

What force would you think is caused by the falling weight? (The answer is upside down at the bottom of this page.)

For this simple situation, the force can be approximated by working out an energy balance. This approach will not work, however, for real-world situations due to the difficulty in calculating the stiffness.

The easy way to predict the result of this or any impact problem is to use Algor's Accupak/VE Mechanical Event Simulation software for Virtual Prototyping. Model the bar and hammer head weight with Superdraw III or your CAD system. Apply the dimensions and material properties in Accupak/VE and it will automatically run the virtual experiment and generate a replay showing the stresses and displacements at any or all instants during the time of the event.

Accupak/VE's Monitor virtual instrumentation program shows results graphically during run time. The Monitor program can show displacement, velocity, acceleration, frequency response, reaction forces and maximum stresses versus time as the event unfolds. Also available is an onboard FFT (Fast Fourier Transform) analyzer that converts displacement versus time into frequency versus energy so design engineers can see the energy absorption spectrum of the model during the event.

For more information on Accupak/VE for Mechanical Event Simulation, contact us or visit our web site at www.algor.com.

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Materials

$MoSi_2$-Based Composite Materials for Aircraft Engines

These lightweight materials may eventually supplant nickel-based superalloys in some components.

Lewis Research Center, Cleveland, Ohio

$MoSi_2$-based composite materials are among the advanced materials undergoing development as potential strong, stiff, lightweight replacements for the nickel-based superalloys now used in aircraft engines. Of the $MoSi_2$-based composites, the most promising ones include SiC-based fibers within matrices that are, themselves, composites of $MoSi_2$ containing 30 to 50 volume percent of Si_3N_4 particles.

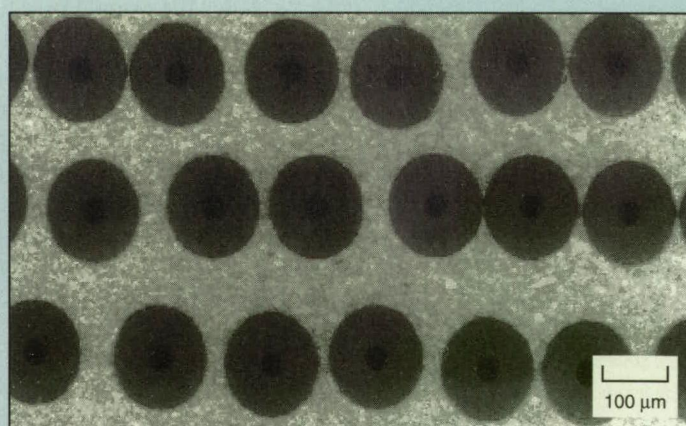
$MoSi_2$ exhibits suitable high-temperature oxidation behavior, along with lower density and higher melting temperature relative to superalloys. However, the use of $MoSi_2$ has been hindered by brittleness at low temperatures, inadequate resistance to creep at high temperatures, a coefficient of thermal expansion (CTE) much greater than that of SiC and other candidate fiber reinforcement materials, and a phenomenon called "pesting" (described in the next paragraph) at temperatures in the approximate range of 400 to 500 °C.

Pesting, also called "pest oxidation," is usually defined as disintegration into powder. Pesting is considered to result from accelerated oxidation, among other things. In the case of $MoSi_2$, pesting involves the simultaneous formation of MoO_3 and SiO_2. In most cases, pesting in $MoSi_2$ has been linked to the formation of voluminous Mo oxides in pores or microcracks.

Since 1985, considerable research effort has been directed toward improving the high-temperature performance of $MoSi_2$ by solid-solution alloying, reinforcement by fibers, and reinforcement by discontinuous inclusions. The present line of development of ($MoSi_2/Si_3N_4$)-matrix/SiC-fiber composites is a logical sequel to previous research that yielded the following findings pertaining to the $MoSi_2/Si_3N_4$ material system:

- The addition of 30 to 50 volume percent of Si_3N_4 particles to $MoSi_2$ increased resistance to low-temperature accelerated oxidation through the formation of a Si_2ON_2 protective scale, thereby eliminating catastrophic pest failure.
- The addition of Si_3N_4 particles also increased compressive strength, fracture toughness, and high-temperature oxidation resistance.
- The brittle-to-ductile transition temperature of $MoSi_2$ containing 30 volume percent of Si_3N_4 particles was found to lie between 900 and 1,000 °C.
- The CTE of $MoSi_2$ containing Si_3N_4 particles was significantly less than that of pure $MoSi_2$. As a result, unlike the matrices in $MoSi_2$-matrix/SiC-fiber composites, the matrices in ($MoSi_2/Si_3N_4$)-matrix/SiC-fiber composites did not exhibit cracking, even after thermal cycling.

To fabricate specimens for experiments along the present line of development, mixtures of $MoSi_2$ and Si_3N_4 powders were prepared, then consolidated by hot vacuum pressing followed by hot isostatic pressing to form fully dense plates of matrix-only ($MoSi_2/Si_3N_4$) material. Specimens of ($MoSi_2/Si_3N_4$)-matrix/SiC-fiber composites (see figure) were prepared similarly, except that multiple plies of SiC-based fibers in various orientations were interspersed with the mixed $MoSi_2$ and Si_3N_4 powders before pressing. (More recently, tape casting was adopted as the preferred technique for processing the fiber and matrix materials with improved fiber spacing, the ability to use narrower fibers, and lower cost.) The two-step consolidation procedure enabled the use of a consolidation temperature lower than that needed if consolidation were effected by hot pressing alone. The use of the two-step, lower-temperature consolidation procedure resulted in a fully dense material without excessive chemical reactions or damage to the fibers.



This **Scanning Electron Micrograph** depicts a cross section of a composite of (1) $MoSi_2$ matrix containing 30 volume percent of Si_3N_4 particles and (2) commercial SiC-based fibers.

The specimens were subjected to a variety of tests to characterize their mechanical, thermal, microstructural, and chemical properties at temperatures ranging up to about 1,400 °C. The results of the experiments agreed with the previous findings and led to the following (among other) additional findings:

- The addition of Si_3N_4 to $MoSi_2$ doubled the room-temperature toughness and reduced the high-tempera-

ture creep rate by about 5 orders of magnitude.

- Reinforcement of $MoSi_2/Si_3N_4$ matrix materials by SiC-based fibers increased room-temperature fracture toughnesses by factors of about 7 and impact resistance by factors of about 5.
- In general, specimens of $(MoSi_2/Si_3N_4)$-matrix/SiC-fiber composites exhibited excellent strength and toughness improvements at temperatures up to 1,400 °C.

This work was done by M. V. Nathal of **Lewis Research Center** *and M. G. Hebsur of NYMA, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16617.

Metal- and Oxide-Containing Carbons Made From Graphite Oxide

These materials can be used in gas sensors, power cells, and catalytic cells.

Lewis Research Center, Cleveland, Ohio

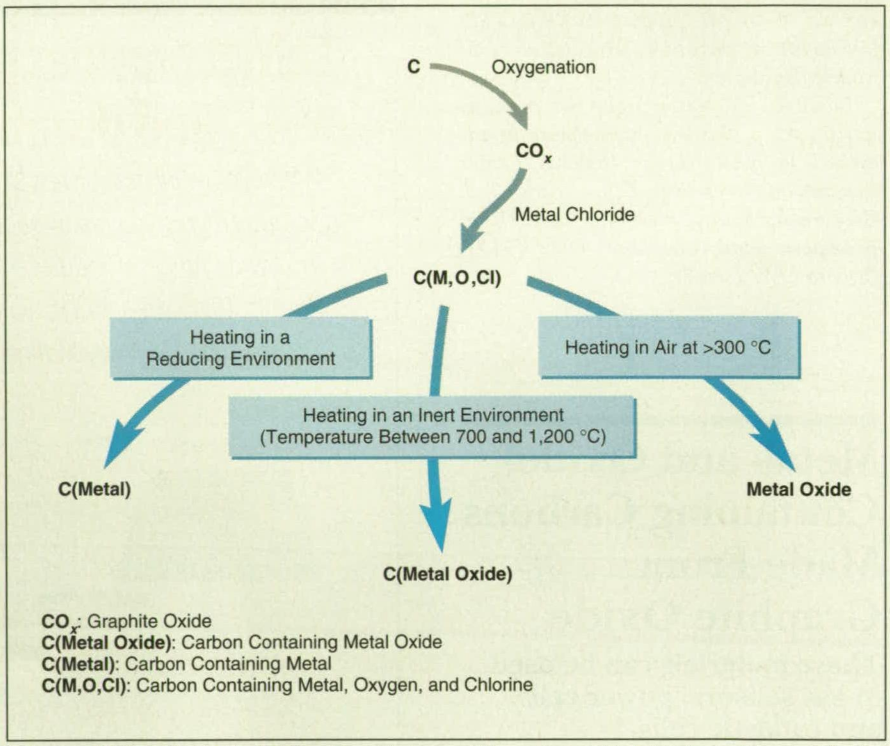
Carbon-based materials containing, variously, metals and metal oxides can be synthesized according to a method that involves reactions of metal chlorides with materials of general composition CO_x. In a typical material synthesized by the present method, the carbon is porous and serves as a substrate for the metal or metal oxide. Depending on the application, the metal or metal oxide could serve, for example, as a catalyst or as an electrode material in a gas sensor or electrochemical power cell. Alternatively, instead of serving as a substrate, the carbon could serve as a template for formation of a porous metal oxide (ceramic), from which the carbon is eventually removed.

Aspects of a related older method were described in several previous articles in *NASA Tech Briefs*, including "Iron-Containing Carbon Materials Made

From Graphite Fluoride" (LEW-16432), Vol. 22, No. 5 (May 1998), page 46 and "Modification of Carbon Fibers for Higher Young's Modulus" (LEW-15847) *NASA Tech Briefs*, Vol. 21, No. 4 (April 1997), page 56. The corrosiveness and toxicity of fluorine and the general difficulty and high cost of synthesizing graphite fluoride make the older method unattractive. Among the advantages of the present method are that in comparison with graphite fluoride, graphite oxide is safer and can be made more easily (under lower temperatures and otherwise milder conditions) and at lower cost.

starting carbon material can be crystalline graphite, amorphous carbon, or graphitized carbon in fiber or powder form. The carbon material is treated as described above to obtain CO_x, which is then exposed to a metal chloride at a temperature between ambient and 200 °C. The metal chloride can be in the form of a solution, a pure liquid, a pure vapor, or a mixture of two or more of these forms. The resulting intermediate product, denoted "C(M,O,Cl)," consists of carbon filled with the metal, chlorine, and oxygen in various proportions.

Heating the C(M,O,Cl) in air at a temperature >300 °C causes oxidation



A **Carbon Material Is Partly Oxidized** to obtain graphite oxide, which is treated with a metal chloride, then heated in a reducing, oxidizing, or inert environment to obtain one of three types of end products.

Denoted loosely as graphite oxide (or sometimes as graphitic oxide or graphite acid), CO_x is a yellow-brown material that was first synthesized in 1859. In most of the known procedures for synthesizing CO_x, graphite is treated with oxidizing mixtures that contain concentrated acids and oxidizing materials. One such procedure, published in 1958, involves the treatment of graphite with an initially water-free mixture of concentrated sulfuric acid, sodium nitrate, and potassium permanganate. This procedure was used to prepare CO_x for use in initial experiments to demonstrate the present method of synthesizing carbon-based materials containing metals and oxides.

The figure illustrates a generic process for making a carbon-based material containing a metal or metal oxide according to the present method. The

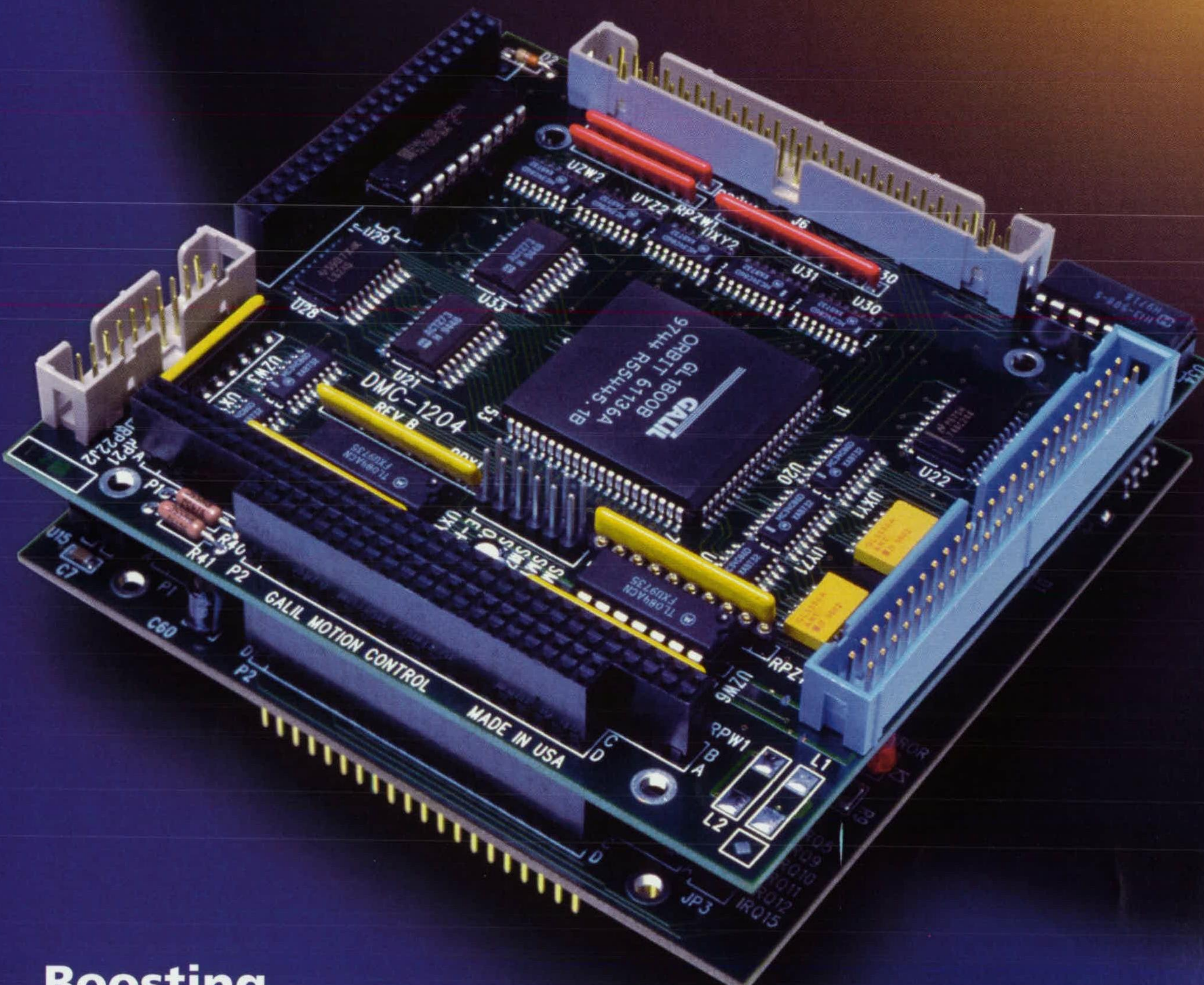
and consequent removal of the carbon and chlorine, yielding a porous metal oxide. Heating the C(M,O,Cl) in a reducing environment yields porous carbon containing metal particles. Heating the C(M,O,Cl) in an inert atmosphere (e.g., N_2 or Ar) at a temperature between 700 and 1,200 °C removes some or all of the chlorine, yielding a porous carbon containing a metal oxide.

This work was done by Ching-cheh Hung of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16342.

September 1998

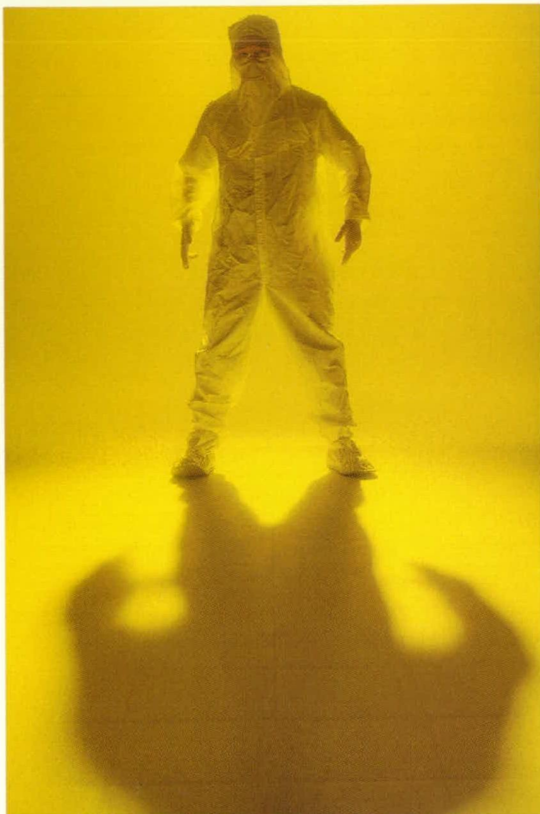
Motion Control Tech Briefs



Boosting Performance with Motion Control Integration

How to Choose a

New Motion Control Products — see page 16b



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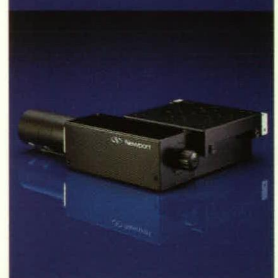
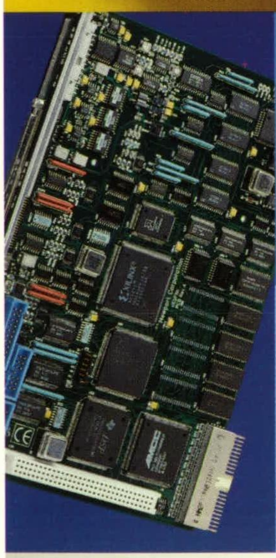
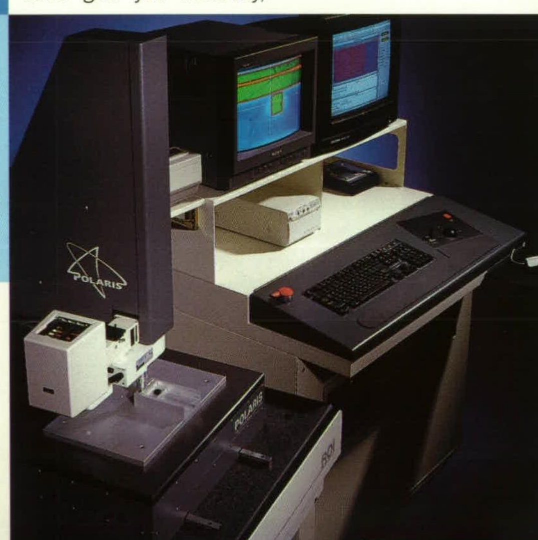


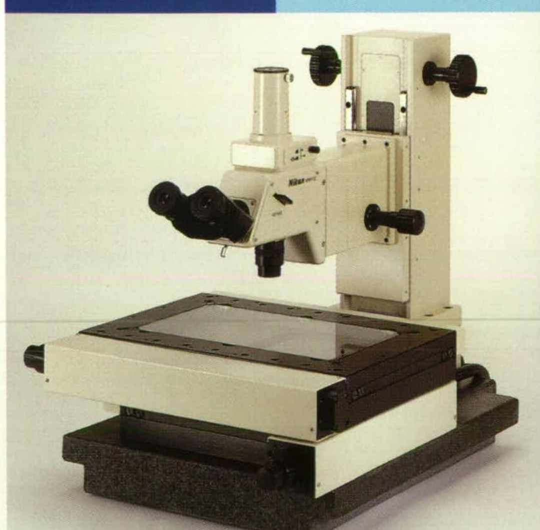
▲ Newport's linear and rotary stages are available in many sizes and configurations for a variety of applications.



◀ The ESP6000 connects to your PC via a single PCI, or compact PCI, plug-in board.



◀ The Polaris system was designed specifically for measuring pole geometry features on thin film disk drive sliders.



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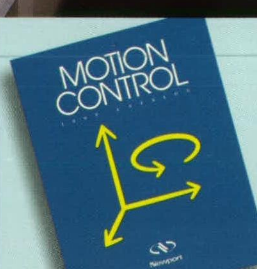

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Motion Control Tech Briefs

Motion Control Tech Briefs Supplement to *NASA Tech Briefs* September 1998 Issue Published by Associated Business Publications

FEATURES

MOTION CONTROL TECH BRIEFS

DEPARTMENT

On the cover:

Galil Motion Control Inc., Mountain View, CA, is making its DMC-1200 series of motion controllers available in multiaxis for the PC/104 bus. Available in 1- through 8-axis formats, they enable control of both step and servo motors on any combination of axes. The series features linear and circular interpolation, contouring, electronic gearing, and ecam. See New Products (page 16b).

Photo courtesy Galil Motion Control.

Gleaning Performance Through Motion Control Integration

Careful engineering is required to make components and systems yield high performance.

System designers face myriad choices today when it comes to specifying the components of a high-performance motion system. In order to achieve optimum results and meet application objectives, it is necessary to consider each of the component technologies individually. Then the integration of them into a working system must be carefully engineered. By breaking down a system into its building blocks, the design task can be approached systematically. Some relatively new components, such as the moving magnet motor and the piezoceramic linear motor, are making engineering easier in some applications. But to start, it is necessary to understand the design terminology and the way to specify a motion system.

The Error Budget

As every engineer knows, each axis of motion has six degrees of freedom (DOF). The objective in axis design is to precisely control one of these (the direction of motion) and minimize the effect of the other five. The unwanted motions resulting from the other DOFs reduce the performance of the overall system. When dealing with x-y or multi-axis motion, the unwanted motions from the DOFs of each axis combine statistically to create the system's error budget (see Figure 1).

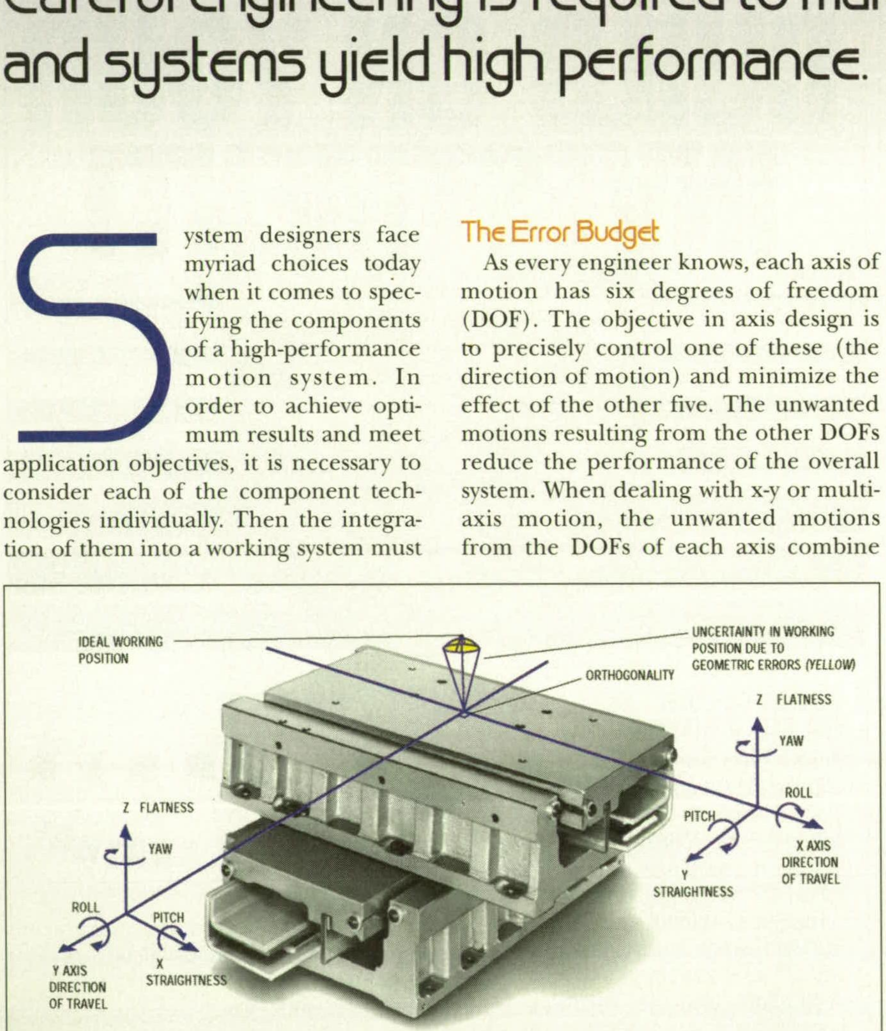


Figure 1. Geometric errors from multi-axis systems combine statistically to produce system error budget (ex: X axis roll combines with Y axis pitch).

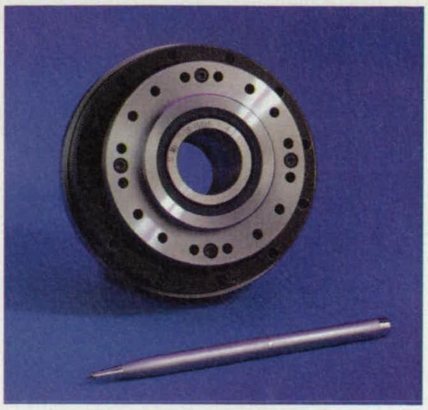
The DOF motions result from several sources, such as imperfection in the bearings, deflection due to loads, thermal distortions, and so forth. The goal in error budgeting is to allocate allowable values for each error source, and select components so that the ability of each to meet its error allocation is not exceeded.

The errors caused by angular deflection are the most troublesome, since these result in Abbe error, which occurs when the point of interest is displaced from the true measuring system. Abbe error is described by the following relationship: Abbe error = offset distance × sine (offset angle). Abbe error makes the indicated position either shorter or longer than the actual position. In some designs, Abbe error is the largest component of the system's error budget. Even a relatively small angular deflection with a moderate offset can result in very significant errors. For example, an angle of only 5 arcsecs and an offset distance of 100 mm results in an Abbe error of 2.5 microns. To quote A. Slocum (*Precision Machine Design*, Prentice Hall, 1992), "Perhaps the greatest sin in precision machine design is to allow an angular error to manifest itself in a linear form via amplification by a moment arm. It is impossible to over-stress the importance of Abbe errors." In other words, a measuring scale provides correct positioning information only at the point where the measuring head attaches.

Accuracy, Repeatability, Resolution

Accuracy, repeatability, and resolution are often used interchangeable, but they have specific meanings. It is important to understand what the application actually requires, and particularly important not to confuse high resolution with high accuracy. Accuracy is much more difficult (and therefore more expensive) to obtain than resolution. Having one doesn't necessarily guarantee the others.

Accuracy and repeatability are



Miniature DC Servo Actuators Mini RH Series

HD Systems offers a line of miniature DC servo actuators for use in applications such as robotics, instrumentation, and factory automation where precise motion control is required. The actuators combine zero backlash harmonic drive gearing with rare-earth magnet DC servo motors to provide both high torque and positional accuracy better than 2 arc-minutes. Rated torques of 2.6 thru 56 in-lb and rated speed of 15 thru 60 rpm are available depending on frame size and gear ratio. The smallest actuator measures just 20 mm in diameter. Encoders and/or tachometers are available as an integral part of the actuator.

HD Systems, Inc. - (800)231-HDSI

Circle No. 605

New, Hollow Shaft Gearing SHF Series

Featuring a through-bore up to 70 mm in diameter, the SHF Series component sets and gearheads enable the design engineer to pass shafting, wire bundles, or other components directly through the center of the gear. The new SHF Series provides high accuracy in a compact design. This unit design is both axially shorter and lower in weight, as compared to conventional harmonic drive gearing. This is accomplished by using HD Systems patented "S" tooth profile. Rated torques up to 6590 in-lb and positional accuracy better than 2 arc-min can be achieved. Gear reduction ratios of 50:1 through 160:1 are available in a single stage.

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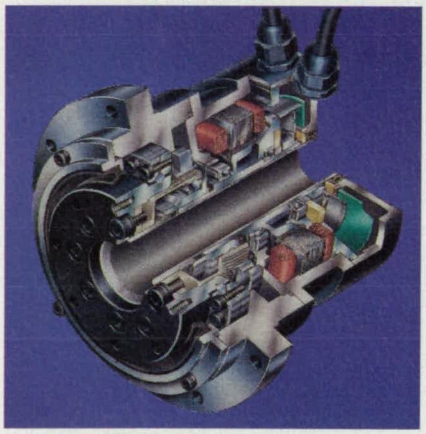

Hollow Shaft DC Brushless Actuators

The FHA Series of actuators feature a through-bore up to 45 mm in diameter and provide high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a patented "S" tooth harmonic drive gear coupled to a DC brushless pancake motor with integral electronic commutation and a high resolution encoder. Rated torques up to 1730 in-lb and positional accuracy better than 1 arc-minute can be achieved. The FHA Series is available in five frame sizes, ranging from 128 to 300 mm in diameter, and 116 to 248 mm in length.

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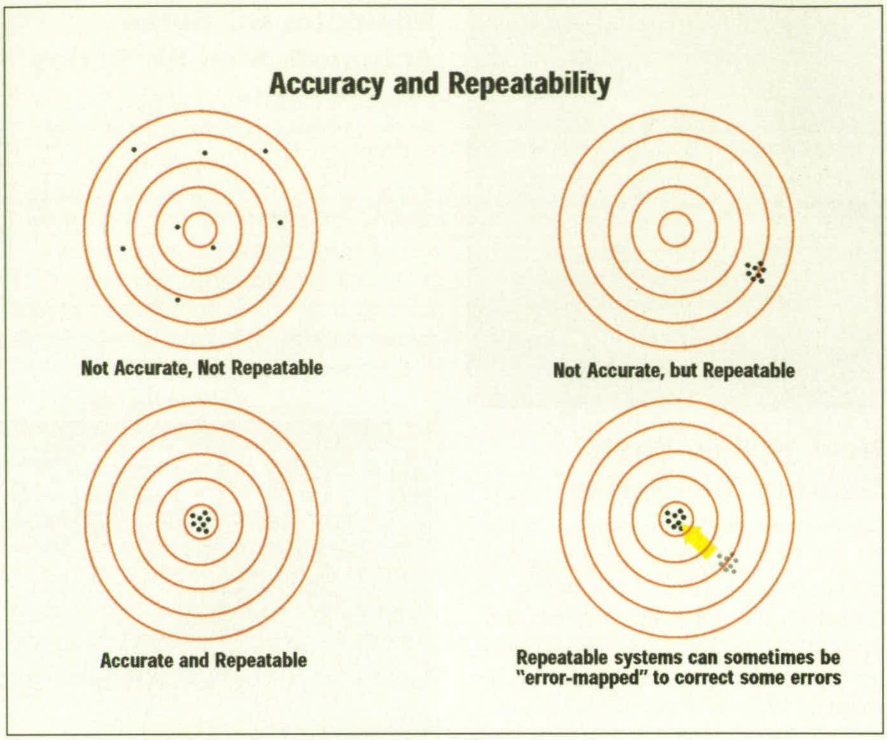

Figure 2. The relationship of accuracy and repeatability.

defined by NMTBA standards. When evaluating different manufacturers' specification, the engineer should verify that they are measured according to this standard. Shown in Figure 2 is a typical accuracy check on a high-accuracy stage, performed with a laser interferometer calibration system.

There are many ways to configure axes to generate x-y motion, including conventional stacked x-y, split axes, single-plane (nonstacked), and gantry. The different configurations have advantages and disadvantages, summarized in Table 1 (see page 8b).

Many types of position feedback are used in precision motion systems. They can be broken down into indirect and direct measurement. The former requires a conversion factor between the indicated measurement and the actual position. A typical example is a rotary encoder mounted to a motor driving a lead screw. The conversion from the encoder to the linear position is: workpiece resolution (counts/inch) = encoder res (counts/rev) × gear ratio (rev/rev) × screw pitch (rev/inch). Since the conversion is not exact due to mechanical tolerances (*e.g.,* lead screw pitch errors, coupling deflections), errors are introduced by this conversion. A better way to measure position is to use direct measurement. Here the position is sensed directly, without the need for conversion. Typical examples include linear encoders, laser interferometers, and 2D grid encoders. Table 2 compares the different feedback types.

As mentioned previously, even systems employing highly accurate feedback can still have significant positioning errors due to Abbe errors. The position feedback devices that do the best job at minimizing these pernicious errors are laser interferometers and grid encoders. Careful design is required to minimize Abbe errors.

Choosing a Bearing

Linear motion can be provided with a wide variety of bearing types. The appropriate choice depends on the requirements of the application. The common choices are linear crossed rollers, linear ball bearing, recirculating ball bearings, and air bearings.

Crossed roller bearings exhibit high load capacity due to their line contact. Linear ball bearings are lower in cost, but they have point contact, reducing load capacity and stiffness. Since linear bearings do not recirculate, they require a longer length to accommodate the bearing motion. They move one half the distance the slide moves. Also, since the bearings move relative to the load, the slide can exhibit large cantilevers at the travel extremes. Recirculating bearings result in a smaller footprint, and the bearing reaction forces are in a constant location with respect to the load. They can support high load capacities, since there are typically several rows of bearings per puck. These bearing are not as smooth as linear bearings, since the balls entering and exiting the raceway can create vibrations.

Air bearings offer the highest mechanical precision, but can be the

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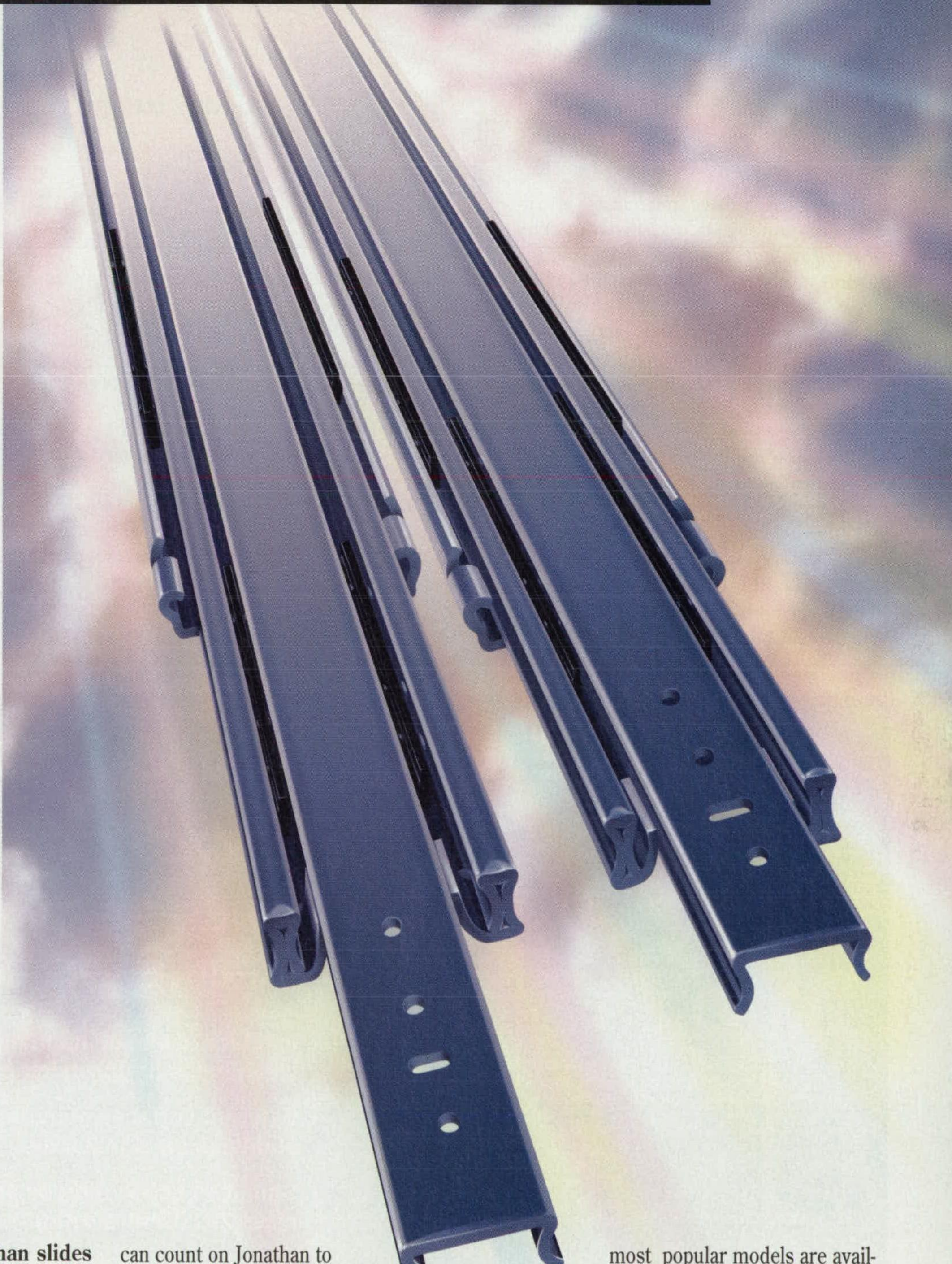
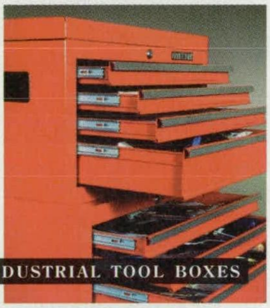


ATM MACHINES



INDUSTRIAL TOOL BOXES

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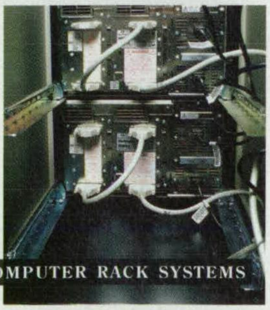

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most costly alternative. They have numerous advantages for very high precision: noncontact drive, which eliminates wear and friction; very high mean time between failures; and no lubrication. Since the bearing essentially glide over a precision lapped reference surface, submicron geometric accuracies can be achieved. Also, since an air bearing can float in two directions, it enables single-plane stage configurations, minimizing Abbe errors.

Selecting a Drive

The choice of drive mechanism is critical to motion-system performance. The most prevalent for high-performance motion control are: lead screw/ball screw with rotary servo motor and encoder; lead screw/ball screw with open-loop microstepper; linear servo motor; and piezoceramic linear motor (friction drive).

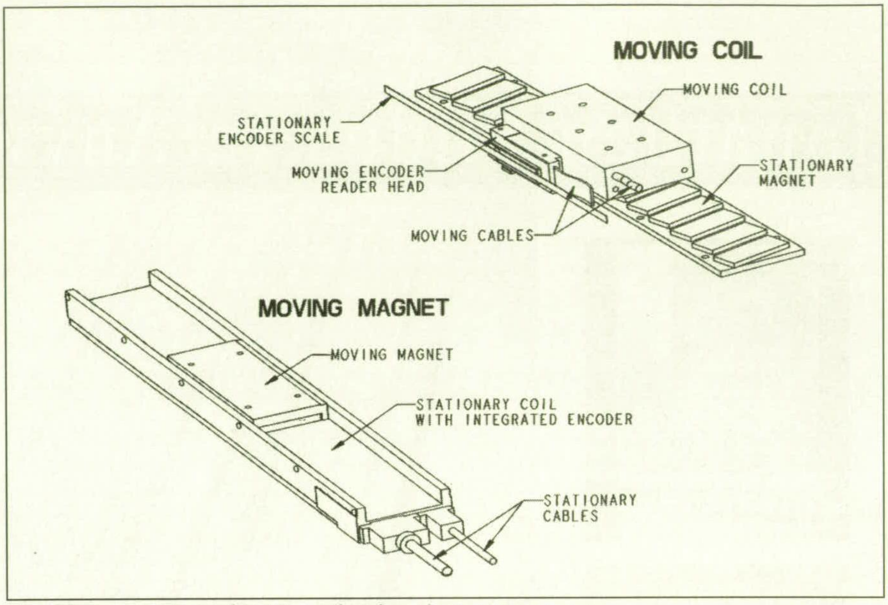

Figure 3. A comparison of moving coil and moving magnet motors.

Lead screw drives are commonly used for precision applications. They provide mechanical advantage due to the lead screw pitch, which is useful for positioning heavy loads. However, they have many limitations, particularly for longer travels and high speeds. Any rotating shaft has a critical speed, above which violent whipping will occur. To overcome this, it is necessary to increase the diameter of the screw, requiring more power and therefore more heat dissipation. Other disadvantages include mechanical backlash, pitch errors, and windup, all of which can limit accuracy and repeatability. In ball-screw-driven systems, the location of the feedback is extremely important.

Linear servo motors are a type of direct drive in that they provide linear thrust to position the load directly, without any intervening mechanical elements. Since there is no linkage, these drives have no hysteresis, windup, or pitch errors. Accuracy is dependent entirely on the bearings and feedback control system. However, since linear

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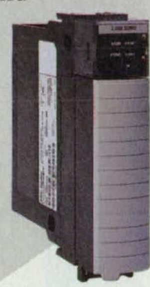

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Minimizes abbe errors	★★	★★★★	★★★★★	★★★
Large workpieces	★★★	★★★★	★★	★★★★★
Heavy workpieces	★★★	★★★★	★★	★★★★★
Long travels	★★	★★★	★★★	★★★★★
High accuracy	★★★	★★★★	★★★★★	★★★
High Speed	★★★	★★★★	★★★	★★★★★
Cost	★★★★★	★★★★	★	★★★

Table 1. Axis configurations. Worst ★ Best ★★★★★

motors have no mechanical advantage, they are not as well suited to widely varying loads nor vertical loads (without a counterbalance). But they can exhibit the highest order of dynamic stiffness, enabling a minimum following error in critical dynamic applications.

Many types of linear motors are available today. The appropriate choice depends on an analysis of the application. Force ratings up to 4000 lb. are available for industrial applications such as high-speed machining. Ultra-smooth nonferrous (slotless) motor designs eliminate magnetic cogging, enabling the highest levels of accuracy and the smoothest motion for critical scanning applications.

A key issue, especially with long travels, is the moving cable of a linear motor. In cases where moving cables are undesirable, motors are available with stationary windings and a moving magnet, a relatively new development. An example is Anorad's Lightning Series. These moving magnet linear motors are designed for simplicity, beginning with the elimination of all moving power and control cables, with plug-and-play capability. This design provides a high degree of safety by eliminating the normally exposed stationary magnets. The integral encoder is suited to general automation applications requiring high velocity to 10 m/s, resolution of 5 microns, and repeatability of ±10 microns. The Lightning Series is highly efficient and typically operates at cool temperatures due to proprietary current-switching technology that charges only the coils under the moving magnet. The series is recommended for general factory automation, including applications such as material handling, pick and place, winding machines, flying shear, metrology, and dispensing.

Piezoceramic linear motors (PCLM) are also a relatively new drive choice, but they have many advantages for precision motion. These devices are a class of friction drive, in that they rely on mechanical friction between a moving "finger" and a drive strip to provide motion. PCLMs are extremely compact and generate almost no heat. They provide exceptional position-hold stability due to their inherent friction combined with their direct-drive characteristics. Position-hold stability of <10 nm has been reliably demonstrated. However, they are not well suited for heavy loads due to their limited force range. Also, their speed is limited to approximately 300 mm/s. PCLMs should be considered for applications requiring nanometer stability, even with power off, fast move and settle for small moves, and applications where magnetic fields are detrimental (*e.g.,* disk drive testing, electron-beam lithography).

The PCLM operates by driving matchstick-sized piezoelectric elements in a cross-polarized configuration. Though each movement of the element imparts just a few nanometers of tangential drive motion to the driven slide, resonant actuation at 40 kHz achieves continuously adjustable velocities to 300 mm/s with accelerations to >1 G (depending on load). The motor provides virtually unlimited travel and negligible heat while mimicking familiar servo-motor dynamics.

PROPERTY	ROTARY ENCODER ON MOTOR	LINEAR ENCODER ON SLIDE	LASER INTERFEROMETER	2-D GRID ENCODER
Direct measurement of slide position	N/A	★★★	★★★★★	★★★★★
Accuracy	★	★★★	★★★★★	★★★★
Minimum step size	★★	★★★★	★★★★★	★★★★★
Minimizes abbé error	★	★★★	★★★★★	★★★★
Assembly ease	★★★★★	★★★	★	★
Cost	★★★★★	★★★	★	★★

Table 2. Feedback types. Worst ★ Best ★★★★★

Materials and Servo Controllers

The structure supporting the motion system, and the materials used to construct the axes themselves, are also extremely critical to motion system performance. Engineering tools such as FEA should be employed to ensure adequate structural stiffness and natural frequency. It is also important that the structure be isolated from vibrations from the surroundings. Pneumatic vibration-isolation systems are essential for environments with high vibrations, or applications requiring submicron tolerances. Typical material choices include precision-lapped natural granite, polymer composites, cast iron, steel, aluminum, and ceramics.

Careful selection of the servo controller and drive amplifier is essential for successful system integration. Servo amplifiers need to be adequately sized for the power required by the application. In general, pulse width modulation amplifiers provide higher power output than linear amps, but linear amplification provides smoother output. Brushless motors (linear or rotary) require commutation. This can be either simple six-step (trapezoidal) or smoother sinusoidal. Most modern high-performance servo controllers include the capability for software commutation using the feedback encoder. This provides the smoothest motion.

The selection of the servo controller is based on the application criteria, such as programming language, interface (bus-based or RS-232), package, etc. Important engineering specifications include servo update rate (at least 125 microsecond), maximum count frequency (>10 MHz), software commutation, and advanced control algorithms (PIDF, notch filter). There are several controllers on the market that meet the needs of high-performance applications.

The successful integration of a high-performance motion control system starts with a review of the application objectives. After developing a concept for the system design, the component technologies are analyzed to make the best selection to achieve the requirements. A systematic building-block approach is the best path to a high-performance working system, without weak links that degrade overall performance.

For more information contact the author of this article, Arthur Holzknecht, Manager of Engineered Systems, at Anorad Corp., 110 Oser Ave., Hauppauge, NY 11788; (516) 231-1995; fax (516) 435-1612; E-mail: arth@anorad.com.

Choosing the Correct Servo Brake

Permanent magnet fail-safe brakes, shown in two body styles and four armature styles.

Fail-safe brakes, or power-off brakes, are employed in servo and stepper motor applications to hold a load or provide emergency stopping. With the ever-increasing torque and speed of servo motors, the need for higher torque and faster response times becomes increasingly evident. In most servo applications, either static holding or emergency stopping applications, the brake must hold or decelerate the load if power is "lost." Servo systems usually accelerate and decelerate the load, and the brakes are used to hold the load.

Up until recently, spring-set brakes have been the brake of choice for most servo applications. These brake designs employ compression springs to push the brake armature against the friction material plate, squeezing the plate between the armature and pressure plate. The brake hub, which is attached firmly to the servo motor shaft, is attached to the friction material plate by means of a spline or hex drive.

To release a spring-set brake, voltage is applied to the coil, which must saturate and attract the armature plate against the spring pressure, thus releasing the pressure on the friction material plate and allowing the motor shaft to rotate freely with the hub and friction material plate. To engage the brake, power is removed, allowing the residual magnetism in the coil to decay sufficiently to permit the spring force to press against the armature plate, squeezing the friction plate.

In the ever-increasing speeds, torques, and positioning of servo systems, the spring-set brake has three major failings:

- **Torque:** With servo motors' greater torques, spring-set brakes can no longer provide the torque needed in the given motor diameter;
- **Speed:** The increasing speed of servos has dictated that the spring-set brake must be released long before the motor is started, so because of the saturation at power-on and the residual magnetism at power-off, spring-set brakes have inherently slow response times;
- **Backlash:** Because of the spline connection between the hub and friction material plate, there is a looseness between these two drive components that can be as great as 5° and can increase with wear over time.

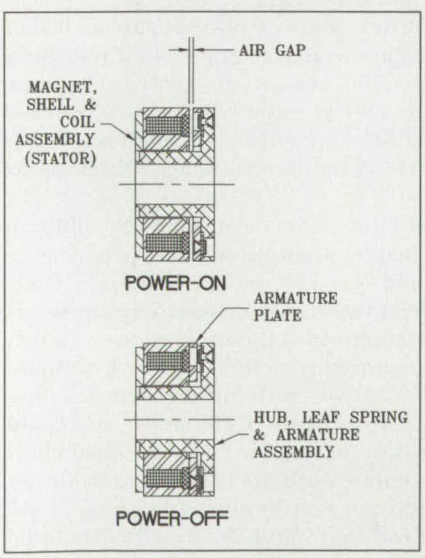
A recent development in power-off brake design is the permanent magnet brake, using neodymium iron boron (NdFeB) magnets and providing high torque, fast response times, and zero backlash. These brakes operate with a permanent magnet field that attracts the armature plate using internal and external poles within the brake body. The armature is attracted by the magnetic field and generates braking torque as a result of the friction between the poles and the rotating armature. For power-on

releasing, as the coil is engaged, the magnetic field produced is in the opposite polarity of the permanent magnet's field, which counteracts that field, allowing the leaf springs to pull the armature away from the poles without leaving any residual brake torque.

Zero backlash is provided by the leaf springs that attached the armature plate to the aluminum hub—not only zero backlash but no rotational contact between the armature plate and the brake body during rotation. This provides an extremely quiet brake without the inherent chatter created by the spline looseness between the hub and friction plate in spring-set designs.

The extremely high torques that are transmitted by the NdFeB brakes are a direct result of the superior magnetic flux density and the coefficient of friction between the steel armature plate and the steel poles. The NdFeB has doubled the torque of previous ferrite (C5) magnetic material and is currently 20% stronger than the prior samarium cobalt magnetic material. In the case of the steel armature on the steel pole faces, if properly burnished or run-in, Electroid has experienced in excess of 0.08 coefficient of friction.

Because of the interaction between the coil, permanent magnets, and leaf springs, coil saturation and residual magnetism are avoided, thus improving response times over spring-set brakes. When the power is removed from the coil there is no wait for the saturation because the permanent magnet's field has been there all the time. The field was merely being "bent away" from the armature plate. As soon as the reverse polarity field of the coil is removed, the already present permanent magnet field reappears instantly. This field then reacts against the armature and extends the leaf springs until the armature comes in contact with the poles.



Permanent magnet brake in two positions.

In power-on releasing, the poles are saturated with the permanent magnet's polarity. The reverse polarity of the coil repulses the permanent magnet field sufficiently to allow the leaf springs to retract the armature, creating an air gap and allowing the armature plate to rotate with the hub and motor shaft. The interaction between the permanent magnet field, the reverse polarity of the field of the coil, the air gap between the armature plate, and the poles, along with the leaf spring pressure, allows the brake to remain released.

Magnet temperature of 120 °C must not be exceeded, and Thermal Class F 150 °C coil temperatures must not be exceeded. Safe operation of a permanent magnet brake dictates that voltages may not exceed the 24 VDC or 90 VDC by 0.745 or 1.15 times the nominal voltage.

For modern servo applications with high torque, fast response, and zero backlash, the brake of choice is the permanent magnet design.

For more information, contact the author of this article, Edward D. Lazorchak, Vice President of Electroid Company, 45 Fadem Rd., Springfield, NJ 07081; (973) 467-8100; fax (973) 467-2606; E-mail: lazorchak@msn.com.

Improved Roller and Gear Drives for Robots and Vehicles

One type is designed to eliminate stick/slip, another to eliminate reaction torque.

Lewis Research Center, Cleveland, Ohio

Two types of gear drives have been devised to improve the performances of robotic mechanisms. One type features a dual-input/single-output differential-drive configuration intended to eliminate stick/slip motions; the other type features a single-input/dual-angular-momentum-balanced-output configuration intended to eliminate reaction torques.

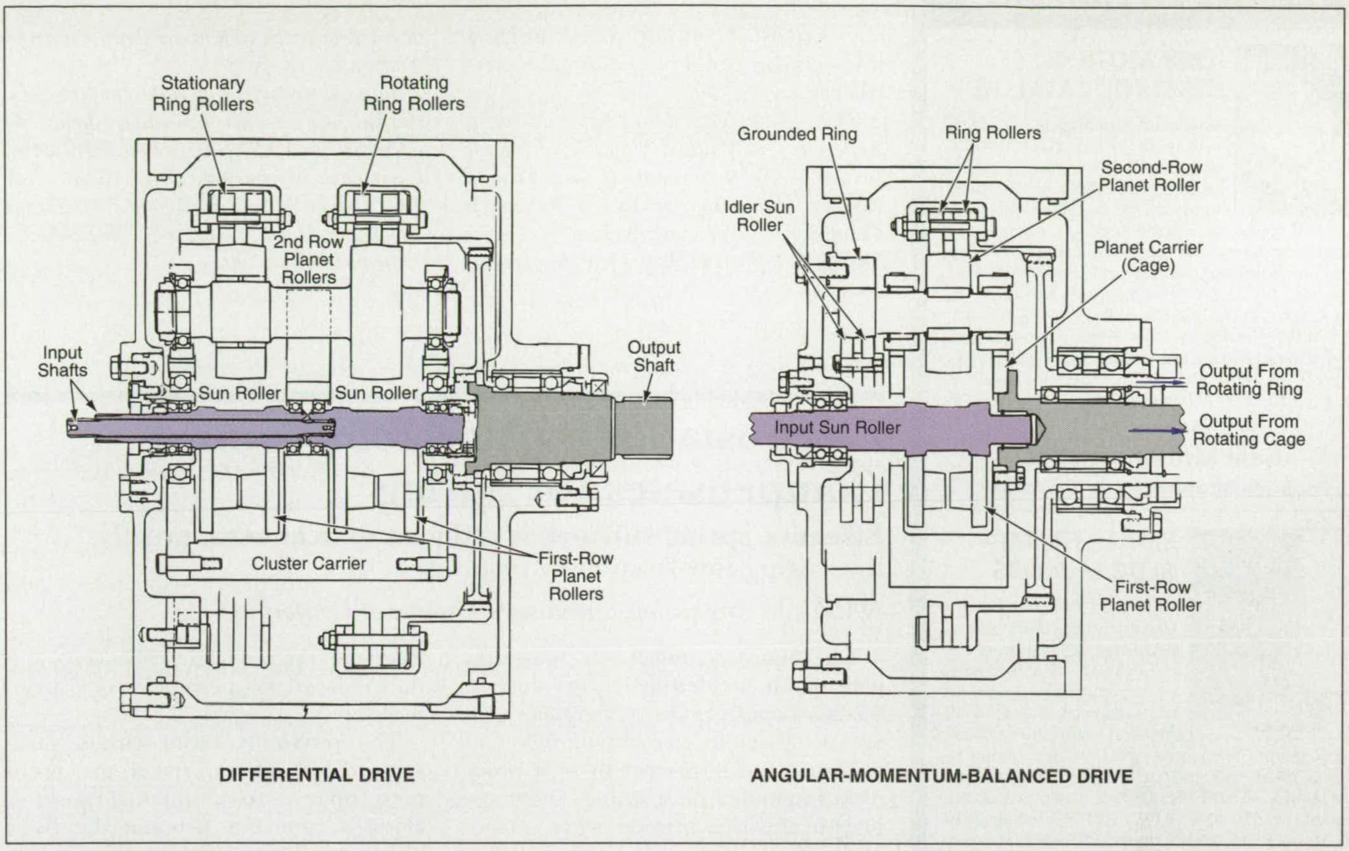
Stick/slip motion can degrade the performance of a robot because a robotic control system cannot instantaneously correct for a sudden change between static and dynamic friction. Reaction torque arises in a structure that supports a mechanism coupled to a conventional gear drive, and can adversely affect the structure, the mechanism, or other equipment connected to the structure or mechanism.

In a drive of the differential type, the two input shafts can be turned at different speeds and, if necessary, in opposite directions, to make the output shaft turn in the forward or reverse direction at a desired speed. This is done without stopping rotation of either input shaft, so that stick/slip does not occur. In a drive of the angular-momentum-balanced type, turning the single input shaft causes the two output shafts to rotate at equal speeds in opposite directions.

The figure schematically illustrates one of two drives of the differential type and one drive of the angular-momentum-balanced type that have been built and tested. Each of the differential drives is rated at input speeds up to 295 radians per second (2,800 r/min), output torque up to 450 N·m (4,000 lb-in.), and power up to 5.6 kW (7.5 hp). The maximum ratings of the angular-momentum-balanced drive are input speed of 302 radians per second (2,880 r/min), dual output torques of 434 N·m (3,840 lb-in.) each, and power of 10.9 kW (14.6 hp).

Each differential drive features either (as explained in the next two sentences) a dual roller-gear or a roller arrangement with a sun gear, four first-row planet gears, four second-row planet gears, and a ring gear. One of the differential drives contains a planetary roller-gear system with a reduction ratio (measured with one input driving the output while the other input shaft remains stationary) of 29.23:1. The other differential drive (the one shown in the figure) contains a planetary roller system with a reduction ratio of 24:1. The angular-momentum-balanced drive features a planetary roller system with five first- and second-row planet gears and a reduction ratio (the input to each of the two outputs) of 24:1. The three drives were subjected to a broad spectrum of tests to measure linearity, cogging, friction, and efficiency. All three drives operated as expected kinematically, exhibiting efficiencies as high as 95 percent.

Drives of the angular-momentum-balanced type could provide a reaction-free actuation when applied with proper combinations of torques and inertias coupled to output shafts. Drives of the differential type could provide improvements over present robotic transmissions for applications in which there are requirements for extremely smooth and accurate torque and position control, without inaccuracies that accompany stick/slip. Drives of the differential type could also offer viable alternatives to variable-ratio transmissions in applications in which output shafts are required to be driven both forward and in reverse, with an intervening stop. A differential transmission with two input drive motors could be augmented by a control system to optimize input speeds for



These **Improved Gear Drives** offer advantages for control of traction and rotary actuation in robots. In addition, drives of the differential type could be used in variable-speed transmissions in automobiles.

any requested output speed; such a transmission could be useful in an electric car.

This work was done by William J. Anderson and William Shipitalo of Nastec, Inc., and Wyatt Newman of Case Western Reserve University for **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16290.

Electrostatic Displacement Control Compensates for Spring

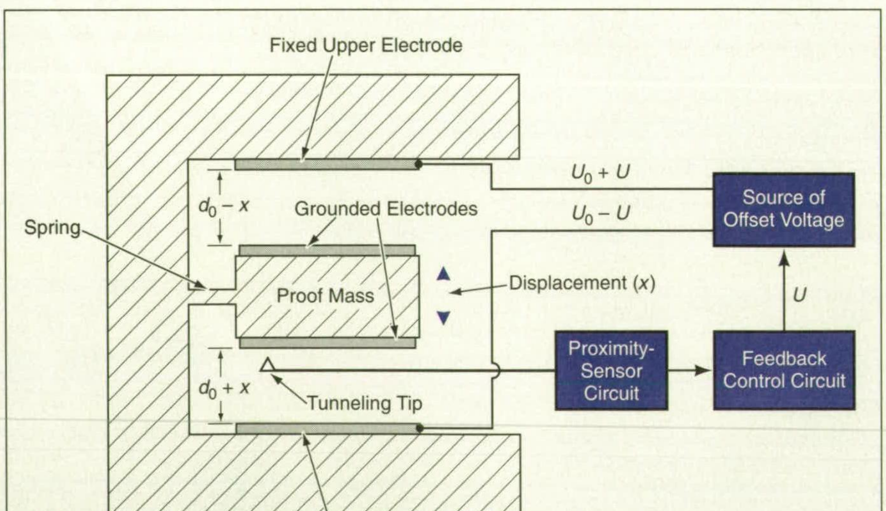
Effective spring stiffness is reduced to near zero, greatly increasing low-frequency response.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure schematically illustrates part of an accelerometer in which a feedback control subsystem applies voltages to generate electrostatic forces to minimize the displacement of a proof mass suspended on a spring. Older systems of this type provide active control of the displacements of proof masses but do not provide any compensation for spring stiffnesses; as a result, low-frequency responses are characterized by displacement errors proportional to mechanical resonance frequencies. The present system differs from older systems in that it operates with a combination of voltages chosen to produce not only active control of the displacement of the proof mass but also passive compensation for the stiffness of the spring. Consequently, in the present system, the effective spring stiffness and resonance frequency are reduced to near zero, and the low-frequency position error is greatly reduced.

The proximity-sensor circuit measures the displacement of the proof mass relative to a nominal position along a direction between the fixed electrodes. The proximity sensor in this system is a quantum-mechanical-tunneling tip, but a capacitor electrode or other suitable device could also be used. The output of the proximity-sensor circuit is processed through feedback control electronic circuitry, which generates electrostatic deflection voltages to drive the displacement toward zero. One of the electrostatic deflection voltages is taken as a measure of the force tending to displace the proof mass, and thus as a measure of acceleration.

The electrodes on the proof mass are



This **Accelerometer Is Similar** to previously reported micromachined spring-and-mass accelerometers with feedback electrostatic displacement control, except that the offset voltage U_0 can be chosen to compensate for the spring stiffness, yielding nearly zero effective spring stiffness and correspondingly increased low-frequency response.

grounded. The voltages applied to the upper and lower fixed electrodes are $U_0 + U$ and $U_0 - U$, respectively, where U is the output voltage generated by the feedback control subsystem and U_0 is a fixed offset voltage that can be chosen to compensate for the spring stiffness. More specifically, one can choose U_0 so that the net component of electrostatic force associated with U_0 and favoring a small displacement is equal in magnitude to the spring force that opposes the displacement.

One can calculate the required value of U_0 with the help of some simplifying assumptions that include linearity of the spring response; coincidence of the nominal, equilibrium, and middle positions; smallness of displacement relative to the equilibrium electrode separation d_0; absence of irreversible processes; absence of slow drifts in mechanical and electronic responses; absence of parasitic feedback loops associated with stray capacitances; and attribution of all errors to noise sources only. In the special case in which the accelerometer is oriented with its sensory (displacement) vertical in a gravitational field and $U = U_g$ is needed to keep the proof mass at the nominal position, the value of U_0 needed to compensate for the spring stiffness is given by

$$U_0 = U_g d_0 \omega_0^2 / g,$$

where ω_0 is the resonance frequency and g is the gravitational acceleration.

In tests, the accelerometer was used to measure small vertical accelerations. Although designed for use aboard a spacecraft, the accelerometer also performed well in normal Earth gravitation: it was demonstrated to respond to accelerations as small as 10^{-6} g, at frequencies from 0.01 to 20 Hz.

This work was done by Benjamin Dolgin, Boris Lurie, and Paul Zavracky of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

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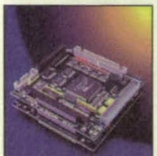
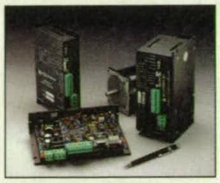


Multiaxis Motion Controllers

The DMC-1200 series of motion controllers from Galil Motion Control Inc., Mountain View, CA, is available in 1- through 8-axis formats for the PC/104 bus, enabling control of both stepper and servo motors on any combination of axes. Galil says that because of their small size—4.4 × 4.15 in.—the controllers are suitable for applications where all of the electronics need to be embedded within a compact area, including semiconductor and medical equipment uses. The series features forward and reverse limits, home inputs, dual encoder inputs for each axis, and uncommitted analog and digital I/O, and up to 12-MHz encoder feedback and 3-MHz stepper speeds.

For More Information Circle No. 780



Brushless Servo Amplifiers

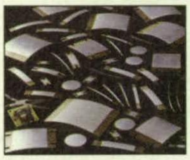
Cleveland Motion Controls, Pittsburgh, PA, has added the MBL and MBLX series of compact brushless servo amplifiers to its Motion Science™ product line. The MOSFET pulse-width-modulated amplifiers provide four-quadrant control in torque and velocity modes. Sixteen board-level and housed models are all designed for motors up to 850 oz.-in. The amplifiers are available in three output voltage ranges (21 to 80 VDC, 40 to 180 VDC, and 100 to 180 VDC) and in three current ranges (6, 10, and 12 A). An on-board +5-VDC 250-mA supply will power an encoder and Hall-effect sensors.

For More Information Circle No. 781

Control Card Option

The VLT 5000 SyncPos Option from Danfoss Electronic Drives, Rockford, IL, is a field- or factory-installed control card option that mounts inside any Danfoss VLT 5000 Series drive from 1-300 HP. It is used for speed control, synchronizing AC motors, and position control. Because it is installed inside the drive, SyncPos preserves the drive's NEMA rating, and requires no extra panel space or wiring. SyncPos can be used in conjunction with fieldbus options including PROFIBUS, DeviceNet™, Modbus Plus, and LonWorks Serial Communications Interfaces.

For More Information Circle No. 782



Piezoelectric Actuators

Based on patented technology licensed from NASA, the Thunder series of actuators from FACE International Corp., Norfolk, VA, are high-displacement piezoelectric devices. The company says that no other actuator in the series' class can match Thunder's mechanical output under load. The actuators owe their performance to the mechanical prestressing of the piezoceramic element within the composite structure, according to FACE. The devices can be made in a variety of sizes and shapes, from a few millimeters to many centimeters. They can be mounted in various multiplexed configurations to amplify displacement and/or force.

For More Information Circle No. 783

Subminiature Recirculating Slide Guides

Del-Tron Precision Inc., Bethel, CT, offers a line of subminiature recirculating ball slide guides with carriages as small as 0.614 in. long, 0.472 in. wide, and 0.236 in. high. The BSG series consists of a block and rail guide, both having two R-shaped raceway grooves machined by precision grinding. Del-Tron says these grooves' large contact area results in a large load capacity and long life. Models are available with rail lengths ranging from 1.575 to 25.197 in. and basic load ratings up to 2205 C lbf. A model using stainless steel for the block and guide rail provides superior corrosion resistance.

For More Information Circle No. 784

Brushless Servo Drives

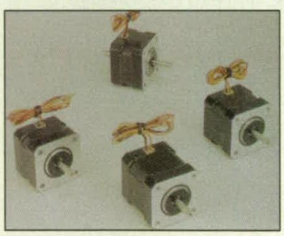
API Controls, Amherst, NY, is making available its Intelligent™ Series of brushless servo drives featuring DeviceNet. These drives replace separate motion controller and drive combinations in most applications with a single serial DeviceNet fieldbus connection to a host. The drives are direct AC-line-operated (115/208/230 VAC nominal), obviating the need for a power transformer. Four models are available with rated continuous output currents of 3, 6, 10, and 20 A, with continuous power ranging from 1.1 to 7.6 kW. Encoder- and resolver-equipped brushless motors are accommodated.

For More Information Circle No. 785

Servoamp with Sinusoidal Commutation

The Model 7225DC from Copley Controls Corp., Westwood, MA, is a servoamplifier for driving AC brushless motors, and especially linear motors, in the torque mode. The company says the device is compatible with a wide range of controllers that derive U and V sinusoidal commutating signals from a motor's digital position encoder; the amplifier synthesizes the third (W) commutating waveform from the U and V signals. It operates from DC power in the range of 45-186 V and develops ±10 A continuous output and ±20 A peak. Copley says the sinusoidal commutation permits motor positioning with micron resolution.

For More Information Circle No. 786



Hybrid Step Motors

Pacific Scientific, Rockford, IL, adds the Size 17 frame POWERPAC hybrid step motor to its line. This series offers a holding torque range from 21.2 to 68.9 oz.-in. and complements the NEMA 34 and 42 frame POWERPAC hybrids. The Size 17 series features a compact housingless frame enclosing 1/2, 1, or 2 rotor stacks. These motors feature single or double shaft extensions, smooth or flat shaft modifications, and 4, 6, or 8 lead terminations.

For More Information Circle No. 787

Corrosion-Resistant Linear Motion System

Bishop-Wisecarver Corp., Pittsburg, CA, offers the Hepco SL2, a stainless steel slide system designed to provide linear motion in arduous environments and in clean rooms. Its aluminum carriage plates are treated with a corrosion-resistant coating, and the slideways are hardened, ground, and finished with a chemical passivating process to promote corrosion resistance. The SL2 comes in a variety of slide widths, including 12, 25, 35, 44, 50, 60, and 76 mm. The company says its low friction characteristics allow dry operation, or cap seals or lubricators can improve system life.

For More Information Circle No. 788

Precision Vibration Isolation

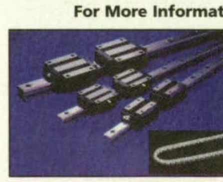
Technical Manufacturing Corporation, Peabody, MA, introduces the Stacis™ vibration control system. It employs a user interface controller and three or four active independent isolators positioned under the equipment they serve. Each isolator houses five piezoelectric actuators and a passive rubber mount 100 times stiffer than standard pneumatic isolators. These actuators control vibration along three axes. Stacis is a six-degree-of-freedom system with a 0.2-Hz resonant frequency, 0.3- to 250-Hz active bandwidth, and a 0.3-second settling time after a step input.

For More Information Circle No. 789

Carbon Steel Ball Valves

The carbon steel ball valves from Parker Hannifin, Cleveland, OH, have a hex-shaped body for easy installation, according to the company. Available in quarter-in. to 2-in. sizes, these ball valves are pressure-rated to 2000 PSI in quarter- to 1-in. sizes, and 1500 PSI in 1-¼-2-in. sizes, with a working temperature range of from -20 to +450 °F. An optional stainless steel ball and stem ensure optimum fluid compatibility, the company says, and optional handles, oval handles, and tee handles are available.

For More Information Circle No. 790



LM Guide with Caged Balls

THK America Inc., Schaumburg, IL, offers the SHS linear motion guide, the latest in its family of caged ball products. THK says the technology reduces ball-to-ball friction and heat for high-speed performance and increased product life, a torque deviation that is one-tenth of traditional models, no ball-to-ball contact for significantly reduced noise, and pockets for lubricant retention for long-term low-maintenance operation. Balls roll through four rows of raceways formed between the LM rail and LM block; each row is arranged at a 45° contact angle for four-way equal load ratings in radial, reverse, and both lateral directions.

For More Information Circle No. 791

Vol. 22, No. 9 September 1998 This form expires: February 28, 1999

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Mechanics

Program Facilitates Simulation of Flows of Cryogenic Fluids

Expertise in numerical simulation is not needed for routine use.

Stennis Space Center, Mississippi

EASY/ROCETS is a developmental computer program for mathematical modeling and analysis of dynamic flows of cryogenic fluids in a rocket-engine-testing facility. Heretofore, the numerical simulation of such flows has been accomplished by use of computer codes specific to test-equipment configurations. The complexity of these codes has made it necessary to employ numerical-simulation experts to modify the software for each new configuration. In contrast, EASY/ROCETS is a modular software package that can readily be modified, by choice of modules, for different configurations. Thus, EASY/ROCETS enables engineers who lack advanced numerical-simulation expertise to construct useful mathematical models of test systems, leading to better testing of rocket engines. In so doing, this software also relieves numerical-simulation experts of the burden of day-to-day involvement in modifications of test equipment, enabling them to devote more effort to development of improved component mathematical models that can then be incorporated into the software.

EASY/ROCETS has been constructed from the EASY5x and Rocket Engine Transient Simulator (ROCETS) programs. EASY5x is a commercial software package that provides a graphical user interface to expedite the layout and modification of a system, plotting capabilities that can be utilized for quick display of data, and a numerical-integration engine with several options for analysis. EASY5x also provides representations of basic control system components, which can be used for modeling test-facility control systems.

ROCETS, developed previously under a contract for NASA, is a modular program that provides mathematical-modeling and numerical-simulation capabilities for analysis of flows in rocket engines. A major underlying assumption of ROCETS, and thus of EASY/ROCETS, is that dynamic flows of cryogenic fluids can be approximated satisfactorily by use of lumped-parameter component models. This assumption is valid in most situations encountered in ground testing of rocket engines.

ROCETS includes modules for calculating pressures, mass flow rates, and heat fluxes for flows of compressible and incompressible fluids in pipes, valves, tanks, and heat exchangers. It also includes modules representing turbomachines, properties of constituent fluids (H_2, O_2, He, and N_2), and combustion of H_2 and O_2.

Prior to the development of EASY/ROCETS, ROCETS in its original form was complex enough that a numerical-simulation expert was needed during use to ensure proper connections among modules. Fortunately, ROCETS fits well within the EASY5x software environment. The aforementioned modules have been converted, and new engineering modules are undergoing development.

A license from Boeing Computer Services is required for the use of the EASY5x component of EASY/ROCETS. The user needs either a UNIX computer workstation or a Microsoft Windows NT computer to run EASY/ROCETS. A FORTRAN 77 compiler and a PostScript printer are also required, regardless of the computer system.

This work was done by Randolph F. Follett and Robert P. Taylor of Mississippi State University for **Stennis Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to SSC-00044, volume and number of this NASA Tech Briefs *issue, and the page number.*

Flush Airdata Sensing System for the X-33 Aerospace Vehicle

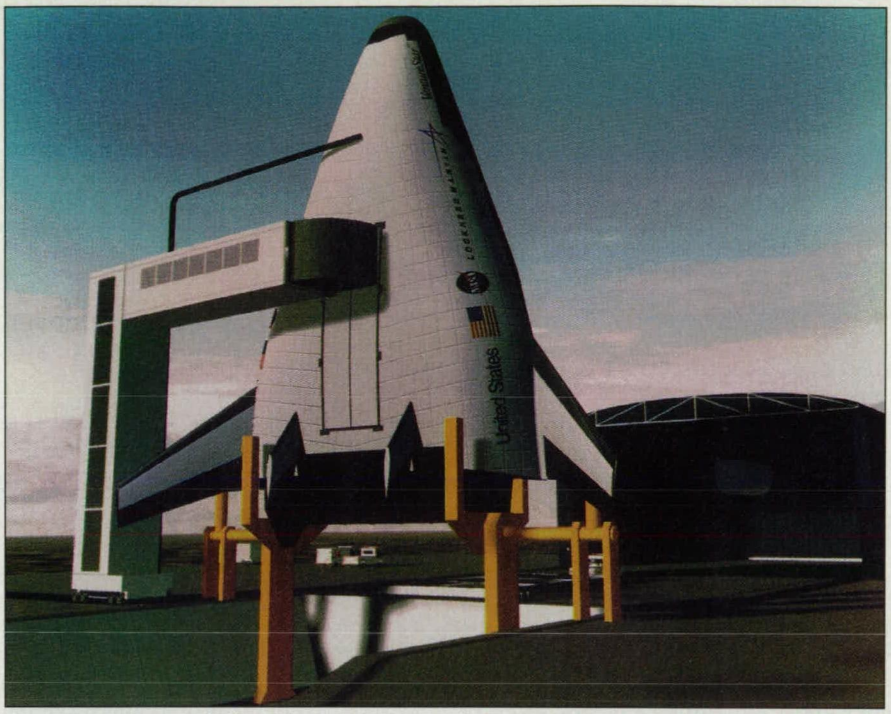
Features include dual redundancy and an improved algorithm for processing measurements.

Dryden Flight Research Center, Edwards, California

A novel airdata system based on flush-mounted pressure sensors has been developed for the X-33 aerospace vehicle. Denoted the "X-33 flush airdata sensing" (FADS) system, it was designed to overcome limitations of pitot-static probes that were used previously, as explained below.

The X-33 is an autonomous, lifting-body-type demonstrator aerospace vehicle designed for use in validating those items of technology necessary for development of a single-stage-to-orbit launch vehicle. The sensors in the original X-33 airdata system were a pair of pitot-static probes (like those used on the Space Shuttle Orbiter) that were deployed on a roll-over mechanism after completion of the high-heat atmospheric-reentry phase of flight. These probes were undesirable for several reasons, including difficulty of integration into the X-33 structure, lack of way to achieve accurate calibration for the first few flights, and lack of a method for measuring sideslip.

The foregoing considerations, along with the success of several recent FADS-system flight-test programs at NASA Dryden Flight Research Center, led to the decision to use a FADS on the X-33 vehicle. The X-33 FADS system was required to provide valid airdata below mach 4 during the launch and landing phases of



The **X-33 Aerospace Vehicle** will be launched vertically like a rocket and will land horizontally like an airplane. It will reach altitudes as high as 50 mi (80 km) and speeds as high as mach 15. It will not carry a crew or cargo; it will be used for testing and demonstration only.

flight, and to remain operational with a single failure anywhere in the system.

An airdata sensing system is needed because the X-33 flight-control and guidance software require the airdata state of the vehicle during the launch, terminal-area energy-management (TAEM), approach, and landing portions of the flight trajectory. Inertial systems are not acceptable because they do not account for wind conditions. Minimizing the angle of attack and angle of sideslip of the X-33 vehicle during the launch portion reduces the loads on the airframe. During the TAEM, approach, and landing portions, the mach number, velocity, and angle of sideslip are used to improve flying qualities and compensate for the wind conditions.

The hardware of the X-33 FADS system measures pressures at six locations on the nose cap of the vehicle. At each location, there are two ports, which are plumbed to individual absolute-pressure transducers to create a dual redundant system with no moving parts. The FADS algorithm, which was developed by Dryden Flight Research Center, includes a calibrateable pressure-distribution mathematical model, through which the measured pressures are related to the vehicle airdata. This model is a splice of (1) the closed-form potential-flow solution for a blunt body, applicable at low subsonic speeds; and (2) the modified Newtonian flow model, applicable at hypersonic speeds. Data from wind-tunnel tests have been used to calibrate the X-33 FADS model for the effects of flow compression, body shape, and such other systematic effects as shock-wave compression or Prandtl-Meyer expansion on the forebody. Once calibrated, the model can be inverted in real time to calculate the airdata state, to the required accuracy, as a function of the measured pressures.

Some innovations have been made to improve upon the previous FADS design for the X-33 application:

- An improved solution subalgorithm for the FADS pressure model makes it possible to decouple (1) the computation of flow-incidence angles, angle of attack, and sideslip from (2) the solution for the mach number, static pressure, and total pressure. This decoupling offers several software and redundancy-management benefits.
- A measure of the error in the pressure-model is used to select the better of the dual-redundant airdata subsystems. This feature makes it possible for both soft and hard failures, including undetected failures, to occur in one subsystem without degrading the airdata computation. This level of redundancy, referred to as "fail-operational," typically requires a mid-value selection of a triple-redundant system.
- A methodology for analyzing the stability of the FADS algorithm was also developed.

This work was done by Stephen A. Whitmore, Brent Cobleigh, and Ed Haering, Jr., of **Dryden Flight Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category. DRC-98-55*

Machinery/Automation

Methodology for Optimizing Designs of Rotating Turbine Disks

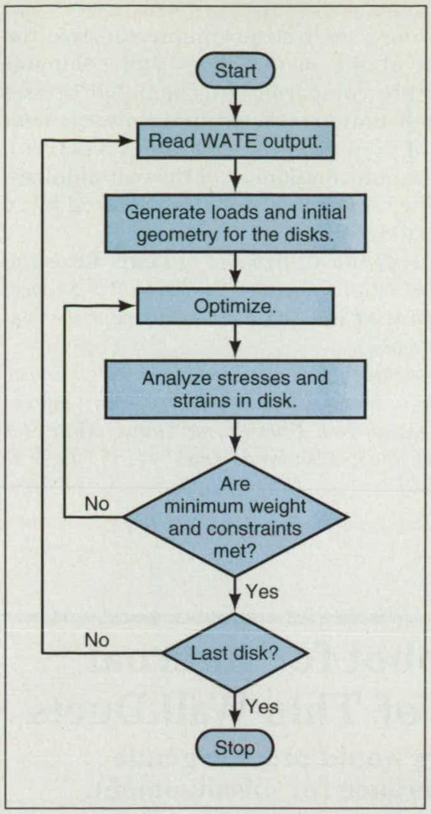
Optimization time can be shortened from as much as three weeks to no more than five minutes.

Lewis Research Center, Cleveland, Ohio

A methodology for optimizing the fundamental structural designs of rotating turbine disks has been developed to aid in preliminary evaluations of various gas-turbine-engine designs. The basis for this methodology is a combination of turbine-disk and low-cycle-fatigue methodologies that was developed in pioneering work published during the years 1947 through 1965. The present methodology goes beyond the previous methodology in that its structural-analysis component is built on an enhanced mathematical model of a rotating turbine disk and is integrated with an optimization component.

In the previous methodology, the mathematical model of a turbine disk was one of constant thickness. In the present methodology, the thickness of the disk can vary with radius in piecewise-linear fashion; in addition, the temperature gradient in the disk is also modeled as a piecewise-linear function of radius. The differential equations of radial and tangential components of stress and strain in the disk are formulated under some straightforward simplifying assumptions (e.g., thickness << radius at all points of interest, and the disk material obeys Hooke's law and is homogeneous and isotropic). The equations are solved numerically by a finite-difference technique.

The incorporation of an optimization procedure saves much time, inasmuch as iterations that would otherwise have to be initiated manually are initiated and completed automatically by a computer. The time saved can be as much as 3 weeks per rotating disk. In this program, the optimization takes no more than 5 minutes. The optimization is performed by the sequence-of-unconstrained-minimizations (SUMT) technique, which is widely used for solving minimization problems that involve linear and nonlinear constraints or unconstrained func-

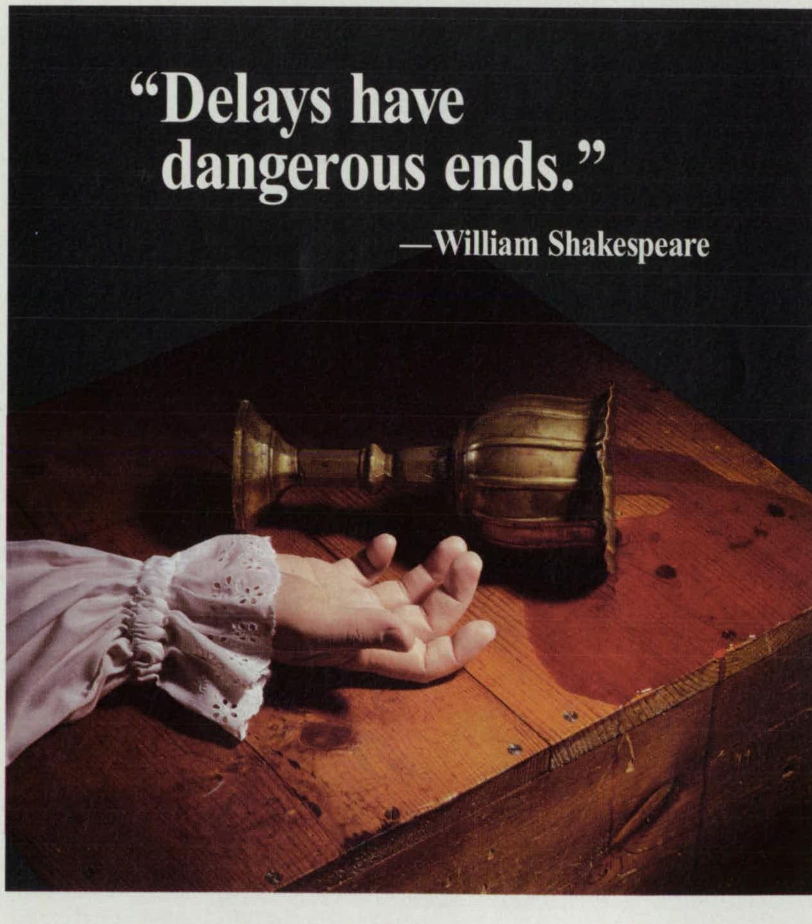


Structural-Analysis and Optimization Procedures are performed by several computer programs that act in conjunction, in response to data acquired from the flow-path-analysis program WATE.

tions. In this case, the objective function that one seeks to minimize is the mass of the disk, while the constraints pertain to maximum allowable levels of stress and relationships among the radii where the slope of the thickness-vs.-radius function changes. The optimization procedure can be summarized as follows:

1. Calculate the loads, stresses, and strains for an initial disk geometry that is based on the chord length of the turbine blades and the radii of the shaft and flow path.
2. Given the geometry and loads calculated, evaluate the constraints.
3. Upon violation of any of the constraints, modify the disk geometry until all constraint equations are satisfied and the mass of the disk is a minimum.

The structural-analysis and optimization components of the methodology are implemented in a computer program, along with a low-cycle-fatigue component adopted from the previous methodology. This program is executed in conjunction with an interface computer program that gathers needed data from a flow-path-analysis program called "WATE" (see figure). The combination of programs requires minimal intervention by the user, and can be used as a postprocessor of the WATE output.



In a test case involving a tenth-stage compressor disk, the stress-analysis portion of the methodology and computer program were assessed by comparing the computed stresses and displacements with those predicted in a finite-element analysis; the two sets of predictions agreed within 3 percent. In a test of the optimization component of the methodology, the mass of the rotating compressor disks was reduced by 26 percent from the initial design mass.

This work was done by Sasan C. Armand of **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16422.

Walking Robot for Internal Inspection of Thin-Wall Ducts

Inflated bladders would provide gentle support with tolerance for misalignment.

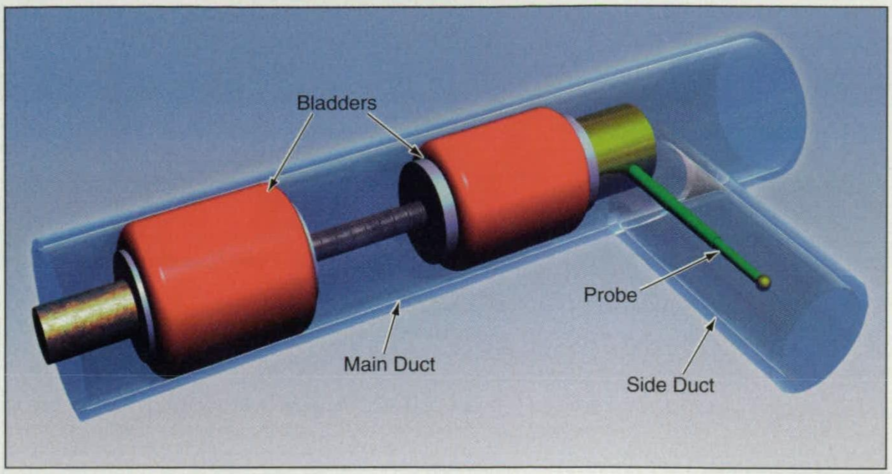
John F. Kennedy Space Center, Florida

A walking robot connected to external instrumentation via a tether has been proposed to enable visual inspections, retrieval of loose objects, and some repairs inside thin-wall round ducts. The ducts in question are made of sections about 4 ft (1.2 m) long, joined by flexible seals that accommodate axial gaps and lateral misalignments of as much as 1/4 in. (6 mm) between sections. The sections can be oriented horizontally or vertically. Some duct sections include, variously, changes in diameter, bends, and openings into side ducts. The robot is required to negotiate all such sections at distances up to 60 ft (18.3 m) from the point of entry, without damaging the thin duct walls. The robot is required to be able to enter a duct through an opening as small as 4.5 in. (11.4 cm) and to move along the duct.

To prevent damage, the load exerted by the robot at a location of contact with a duct wall must be limited to 2.5 psi (17 kPa) or less. The total weight of the robot (including repair and retrieval tools and inspection video cameras but excluding the tether, tether reel, and external instrumentation) must be less than 20 lb (9 kg). The tether [61 ft (18.6 m) long] must weigh less than 10 lb (4.5 kg).

The basic requirements for gentle support, tolerance of misalignment between sections, and ability to accommodate bends would be satisfied by use of bladders that would be inflated after the robot had been placed inside the duct (see figure). The inflation pressure would be just enough to support the robot approximately centrally within the duct and to generate sufficient friction between the bladders and the duct wall to keep the robot from sliding along the duct wall when motion was not desired.

The robot would walk in a quasi-inchworm fashion by a combination of electrical and mechanical actuation, which would include alternate inflation and deflation of the fore and aft bladders in coordination with alternate lengthening and shortening of the structure between the bladders. Moreover, the inflation of both bladders during a stop would orient the axis of the robot approximately along the local duct



Bladders Would Be Inflated to support the robot gently within the main duct. In addition to enabling visual inspection of the interior of the main duct, the robot could extend a probe for inspection of an adjacent portion of a side duct.

axis, thereby providing a directional reference for interpretation of images from the cameras.

This work was done by Dimitrios Apostolopoulos and Warren C. Whittaker of RedZone Robotics, Inc., for **Kennedy Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to KSC-12001, volume and number of this NASA Tech Briefs *issue, and the page number.*

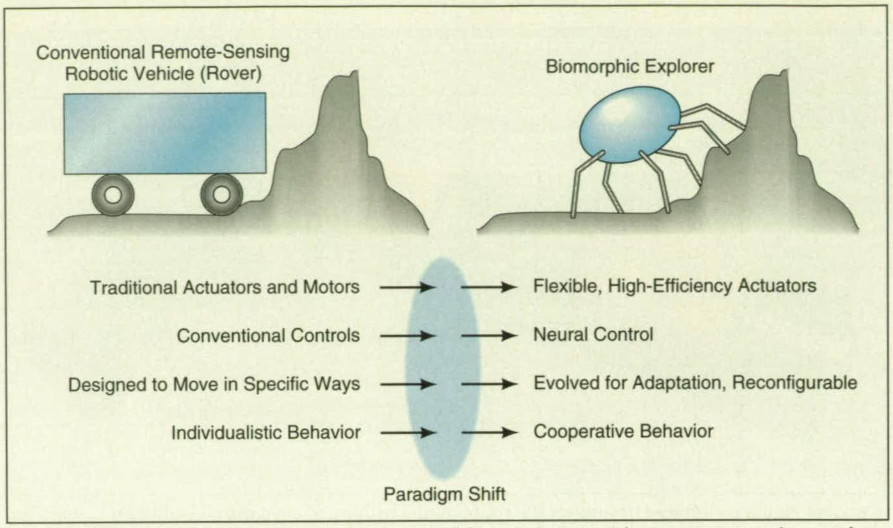
Biomorphic Explorers

Exploratory robots would feature animallike adaptability and mobility.

NASA's Jet Propulsion Laboratory, Pasadena, California

"Biomorphic explorers" are a class of proposed small robots that would be equipped with microsensors and would feature animallike adaptability and mobility. These robots would capture key features, a specific design or function found in nature, taking advantage of general animal mechanical designs and neural functions that have evolved to enable animals to move through various environments. These robots are conceived for use in remote, hostile, and/or inaccessible terrestrial and other planetary environments, where they would be used to perform such diverse functions as acquisition of scientific data, law-enforcement surveillance, or diagnosis for precise, minimally invasive medical treatment. Depending on the specific environment to be explored, a biomorphic explorer might be designed to crawl, hop, slither, burrow, swim, or fly.

The biomorphic-explorer concept is a generalization and encompasses the nanorover concept reported in "Tetherless, Optically Controlled Nanorovers" (NPO-19606), *NASA Tech Briefs,* Vol. 21, No. 3 (March 1997), page 92. Like nanorovers, biomorphic explorers would exploit the emerging technology of microelectromechanical structures. Biomorphic explorers would be enabled by a unique combination of direct-driven, flexible, shape-reconfigurable advanced actuators and their adaptive control by fault-tolerant biomorphic algorithms. Typically, these actuators would consist largely of composites of thin piezoceramic films on strong polymeric substrates and/or combinations of shape-memory-alloy actuators. The actuators would generate forces and/or displacements in response to light or to applied voltage; that is, they could be controlled photonically or electronically. The desired combinations of mobility and adaptability, along with fault tolerance and a limited capability for "learning," would be achieved by integrating the actuators with very-large-



The **Development of Biomorphic Explorers** would be consistent with a current trend away from conventional, limited-mobility robots toward highly mobile, adaptive robots based partly on biological concepts.

scale integrated (VLSI) circuits that would implement neural-networks utilizing genetic algorithms.

Relative to conventional remote-sensing robotic vehicles, biomorphic explorers would be simple, inexpensive, and easy to fabricate; this raises the possibility of mass production of expendable biomorphic explorers that could be deployed in large numbers, possibly acting cooperatively under central control or distributed control. Such deployment would of course, resemble the behavior of colonies of insects or other groups of small social animals engaged in cooperative activity.

This work was done by Sarita Thakoor and Adrian Stoica of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20142, volume and number of this NASA Tech Briefs *issue, and the page number.*

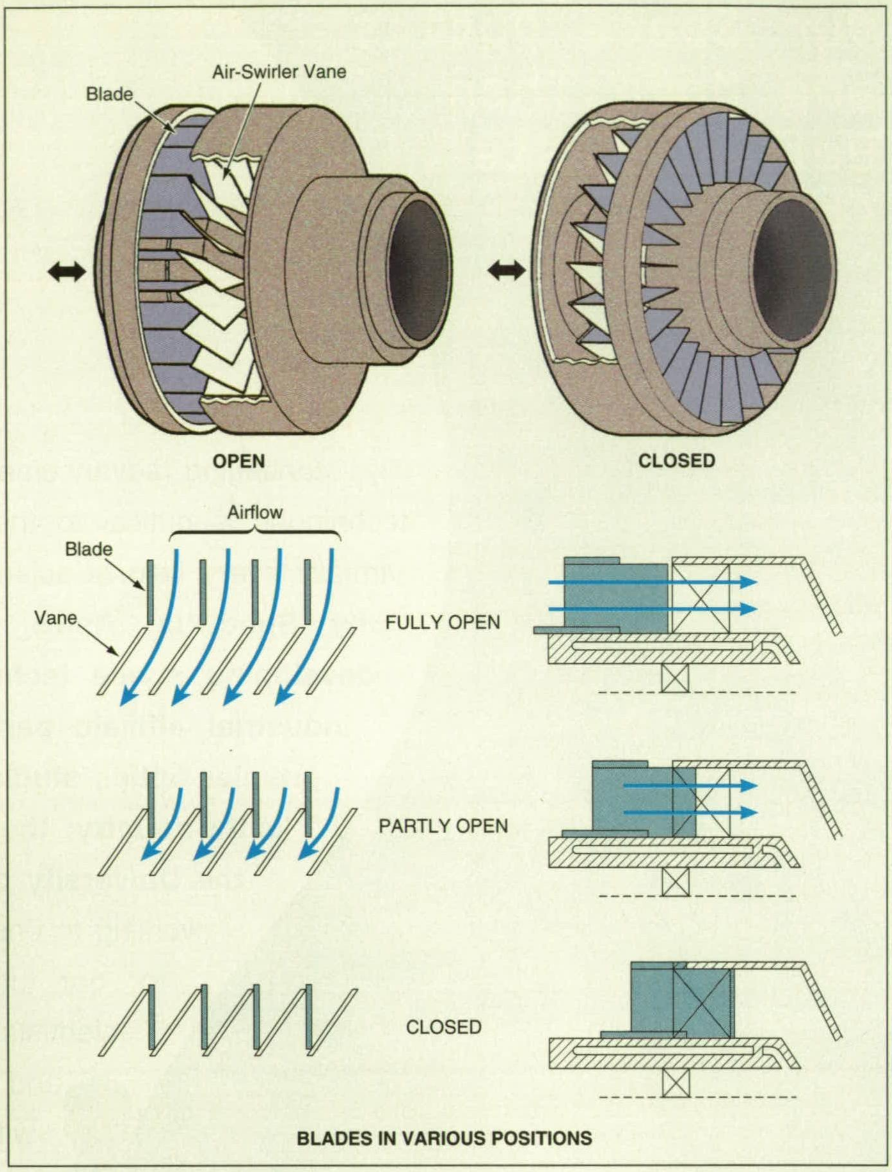
Rib Valve as Shutter for Air Swirler in Combustor Nozzle

Airflow can be adjusted to suit the variable configuration of the combustor.

Lewis Research Center, Cleveland, Ohio

A rib valve is under consideration for use as a shutter in an air swirler in the fuel nozzle of a variable-geometry combustor. In the original application, the variable-geometry combustor would be part of an engine in the High-Speed Civil Transport. In this application, the rib valve/shutter would provide the variable-geometry airflow needed for proper functioning of the combustor under various operating conditions, including rich burn, quick quench, and lean burn. In this context, "proper functioning" means not only smooth and efficient operation but also minimization of quantities of harmful exhaust gases. The rib-valve and variable-geometry combustor design might also be adaptable to any future gas turbine engines.

The rib valve is built into the air swirler (see figure). The air-swirler vanes are mounted in a stationary subassembly. The ribs are straight blades that are located between the air-swirler vanes and are mounted in another subassembly that can be moved axially to insert the blades between the vanes or withdraw the blades from between the vanes. When the blades are fully with-



Ganged Blades are moved axially between the air-swirler vanes to obtain the required degree of partial blockage of airflow.

drawn, the air flows axially into the swirler, with very little obstruction — almost as though the blades were not present. When the blades are inserted all the way, the passages between the vanes are blocked, shutting off the flow of swirling air. Flow conditions between these extremes are obtained by moving the blades to intermediate positions.

The rib valve offers advantages over a block valve that is similar except that (a) throttling is effected by an annular disk, the axial position of which can be adjusted to obtain various degrees of partial blockage of the inlet to the air-swirler-vane subassembly and (b) as a consequence, air enters radially, then turns to flow axially. The effective opening area of the block valve in the fully open position is about 10 percent less than that of the rib valve in the fully open position; as a result, the pressure loss in the block valve is almost 20 percent more than that in the rib valve.

One of the consequences of the rib-valve design is that the velocity of the airflow is nearly uniformly high across the radial flow gap. This is an advantage in that high velocity is needed for adequate atomization of fuel near a fuel filmer in the nozzle. In the block valve, the velocity is low near the fuel filmer, and the flow profile is skewed when the valve is half open.

This work was done by Qiang Wang of United Technologies for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16033.

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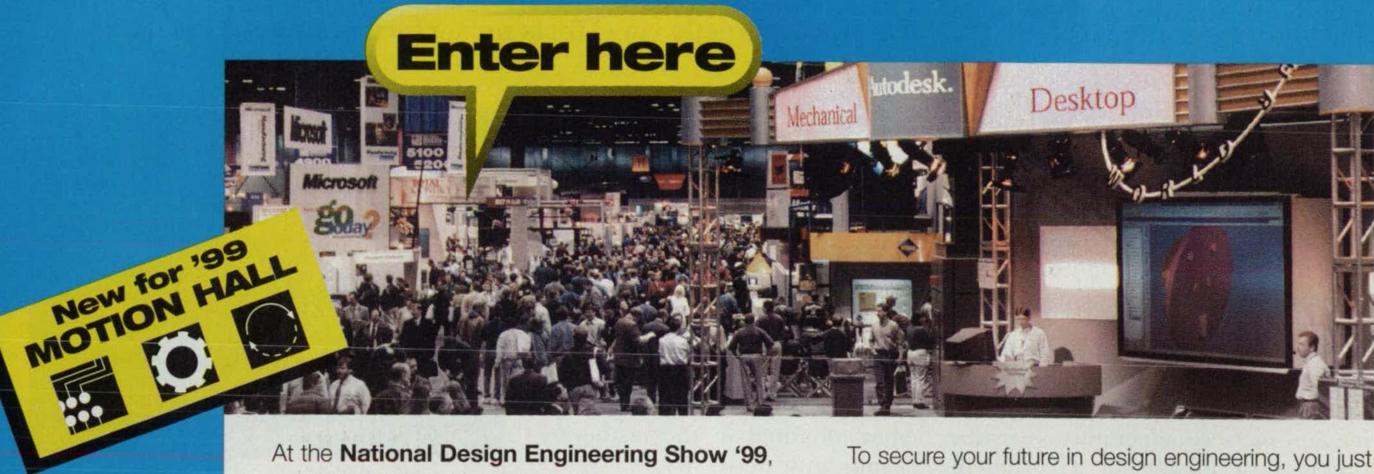

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Remote In-Flight Infrared Imaging for Analyzing Surface Flows

Thermograms reveal some flow features indirectly via effects on surface temperatures.

Dryden Flight Research Center, Edwards, California

The feasibility of remotely acquiring infrared images (thermograms) of aircraft surfaces in flight to locate flow-transition boundaries has been investigated. As used here, "remotely" means that the infrared instrumentation is mounted aboard an observing aircraft that flies along with an observed aircraft, the surface flow on which one seeks to analyze.

Infrared thermograms are, in effect, maps of surface temperatures. Because the rate of mixing in a turbulent boundary layer is greater than in a laminar boundary layer, the turbulent boundary layer transfers heat between the freestream and a surface at a rate greater than that of the laminar boundary layer. Therefore, a surface that is initially warmer than the freestream exhibits a higher temperature in the presence of a laminar than in the presence of a turbulent boundary layer. Similarly, a surface that is cooler than the freestream exhibits a lower temperature in the presence of a laminar than in the presence of a turbulent boundary layer. Therefore, further, one can utilize a thermogram that shows adjacent surface regions with different temperatures to locate the transition between turbulent and laminar boundary layers on the surface.

In-flight thermograms have been acquired from a camera located in or on the aircraft of interest. This approach entailed a number of limitations and disadvantages, including a small field of view and the time and cost of instrumenting each aircraft that one seeks to observe.

In initial tests of the present remote-observation approach, the observing aircraft was an F-18 airplane equipped with a remotely actuated infrared camera and tracking system, and the observed aircraft was a T-34C airplane (see figure). Surface areas of interest were treated by covering them with thin black vinyl contact sheets to minimize reflections, to reduce thermal conductance into the structure, and to raise surface temperature through solar heating.

It was determined from the results of these tests that the desired thermograms can be acquired remotely, and that transition locations and patterns can be extracted from the thermograms. It was also determined that with optimal geometry between the observed and observing aircraft, spatial resolution as low as 0.1 in. (2.5 mm) can be realized. The fields of view obtained in the tests were significantly wider than those in similar images obtained with an on-board system. The images obtained were comparable in quality to those obtained with an on-board system.

Plans for research to be performed in the near future call for obtaining images from a business jet and a large transport airplane, attempting to depict local shock waves and flow separation in addition to laminar-to-turbulent flow transition, and obtaining images without vinyl surface treatment.

While the remote-observation approach has been found to overcome most of the disadvantages of the previous on-board approach, it entails limitations of its own. These limitations include distortion caused by relative motion between the airplanes during image frames and by changes between observational geometries in successive image frames. Research has been performed to develop a capability to process image data to correct for such distortions and to effect general enhancement of images (e.g., to increase signal-to-noise ratios and optimize contrasts).

This work was done by Daniel W. Banks of **Dryden Flight Research Center** *and C.P. van Dam and Henry J. Shiu of U.C. Davis. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
DRC-98-73

The Boundary Between Laminar and Turbulent Surface Flows on the wing of a T-34C airplane can be seen in a thermogram acquired by instrumentation aboard an F-18 airplane flying nearby.

Transparent Furnaces for High-Temperature Research

Optical access will contribute to diagnosis and feedback control.

Lewis Research Center, Cleveland, Ohio

Transparent furnaces are being developed for use in research on properties and processing of materials at high temperatures. Full optical access to the interiors of furnaces is intended to provide the capability for nonintrusive diagnosis and feedback control of the subtleties of high-temperature processes. Small furnace windows are now included in some otherwise opaque furnaces to provide visibility for assessing crystal quality, but only small portions of the objects of interest can be viewed, and these windows cause thermal disturbances that affect crystal-growth processes.

A standard transparent furnace of the type developed thus far includes a quartz tube that is coated with a thin layer of gold and that surrounds the hot zone. The gold layer is about 80 percent transparent to visible light and about 95 percent reflective to infrared radiation; thus, it enables visual observation of the interior of the furnace while acting as a radiant heat insulator to impede leakage of heat from the furnace.

The furnace is heated by one or more helically wound resistance heating coils. The pitch of the coils is made large enough to make it possible to look between the turns of the coil(s) and see the interior region of interest. A quartz shield tube is located between the heater and the gold-coated mirror surface to prevent the outgassing heater material from coating the gold and thereby reducing its infrared reflectivity. A quartz "muffle" tube is mounted as an impurity barrier between the heater and the material sample to be heated and observed. Typically, the hot zone is 6.5 cm in diameter and 13 cm long, and a controlled atmosphere is maintained in the hot zone.

Standard transparent furnaces developed thus far have been limited to operating temperatures below 1,000 °C. Transparent furnaces at the leading edge of development are being modified for operation at higher temperatures; the modifications include improvements in containment of thermal radiation, reduction in convective transfer of heat, the use of materials that are transparent at high temperatures, and improved design of transparent-heater components. In a theoretical analysis that coupled energy-balance analysis and heat-shield design with modifications of a commercial transparent furnace, it was shown to be feasible to raise the maximum operating temperature to 1,200 °C.

This work was done by David W. Yoel of Centorr/Vacuum Industries, Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16064.

Measurements of Radiation in the Atmosphere

These measurements are needed to understand changes in climate.

Dryden Flight Research Center, Edwards, California

The recent summit meeting held in Kyoto, Japan, has brought world-wide attention to the issue of global climate change. For the past 5 years, the Department of Energy's Atmospheric Radiation Measurement - Unmanned Aerospace Vehicle (ARM-UAV) Program has been investigating the largest source of uncertainty in global warming; the interaction of solar radiant energy with clouds. As the program name implies, ARM-UAV is fostering the development of UAVs and developing specialized instruments for measurements related to climate research.

It was recognized from the outset that certain key parameters, such as atmospheric heating and cloud-top properties, are best measured in the atmosphere. The endurance and altitude requirements for these measurements appear to be best met by an emerging class of small, long-endurance, high-altitude UAVs, which complement, but do not eliminate the need for, piloted aircraft, satellites, and surface instrumentation.

In September 1996, ARM-UAV conducted a month-long flight series that culminated in an unprecedented scientific flight extending over a complete day-to-night-to-day cycle (26 hours, 11 minutes). For this flight series, ARM-UAV mounted its payload in the first Altus UAV (see figure), which was built for the NASA Environmental Research Aircraft and Sensor Technology (ERAST) program by General Atomics/Aeronautical Systems, Inc. The ERAST program is managed by Dryden Flight Research Center. This Altus UAV was flown in conjunction with the U.S. Navy's Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS). ARM-UAV purchased the second Altus UAV for long-term use as an instrumented platform to demonstrate instruments and measurement techniques as well as to acquire initial atmospheric data. The second Altus UAV was first used in a similar month-long flight series in September, 1997, over the DOE's Cloud and Radiation Testbed site in north central Oklahoma.

The primary scientific focus of the ARM-UAV program is on radiation/cloud interactions in atmosphere of the Earth. Uncertainties in how clouds interact with solar and thermal radiation account for almost the entire factor-of-three variation in the predicted temperature rise resulting from a doubling in the carbon dioxide content of the atmosphere. An important aspect of the program is the use of UAVs as the primary airborne instrumentation platforms. UAVs are capable of extended flight at altitudes $\geq$ 65,000 ft ($\geq$ 20 km), making it possible to take continuous measurements with a set of well-calibrated instruments above the tropopause, and thus above the troposphere, which is the lowest layer of the atmosphere where most clouds and weather occur.

The ARM-UAV payload consists of state-of-the-art radiometric instruments, positioned to make measurements above and below the aircraft, and instruments to make such supporting measurements as those of temperature, pressure, and concentration of water vapor. A second, similar payload with the same radiometers is typically flown in a de Havilland Twin Otter airplane, operated by Ross Aviation, flying directly below the Altus UAV. A particularly valuable flight pattern places the Altus UAV above a cloud layer and the Twin Otter below, forming a "cloud sandwich." The simultaneous measurements obtained by the Altus and Twin Otter instruments in this configuration are invaluable in understanding the role of clouds in absorbing and reflecting solar energy.

This **Altus UAV** was photographed in flight over Oklahoma during the ARM-UAV flight series.

From the outset, ARM-UAV has been a multiagency program, bringing together the best capabilities available within government agencies, universities, and private industry. Sandia National Laboratories provides overall technical direction, along with logistical planning and support, handling of data, and a multispectral imaging instrument. Other instruments are provided by Goddard Space Flight Center, Ames Research Center, Lawrence Livermore National Laboratory, Brookhaven National Laboratory, and universities, including Colorado State University and the University of California Scripps Institute. University scientists participating in ARM-UAV are also drawn from the University of Maryland, the University of California at Santa Barbara, Pennsylvania State University, the State University of New York, and others.

The next planned ARM-UAV flight series will be a joint activity with the NASA ERAST program to be conducted in September 1998, from Kauai, Hawaii. The ARM-UAV payload will be installed in the ERAST Altus UAV now being modified to enable flight to altitudes as high as 65,000 ft (20 km). This higher altitude capability will be used to investigate the properties of tropical cirrus clouds.

This article was written by W. R. Bolton of Sandia National Laboratories and describes work done in cooperation with **Dryden Flight Research Center.** *For further information, see below or access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to DRC-98-32, volume and number of this NASA Tech Briefs *issue, and the page number.*

Optical Remote Detection of Ice on Aircraft Surfaces

The thickness of ice can be estimated from spectral reflectance.

NASA's Jet Propulsion Laboratory, Pasadena, California

An imaging spectroscopic technique is undergoing development for use in remote detection of ice and mapping of the thickness of ice on aircraft surfaces. The technique is based on the variation of local spectral reflectance with the depth of ice and/or water on a surface of known aircraft material (typically, aluminum). The spectrum of white light reflected from each surface point includes absorption dips characteristic of any water or and/or ice present at that point, as distinguished from the relatively flat spectral reflectance of aluminum. Thus, the local thickness of ice (and, optionally, water) can be computed from the local spectral reflectance, and the thickness of ice can be mapped by performing this computation for all points in the image.

In experiments to demonstrate the technique, a band-pass liquid-crystal tunable filter (LCTF) and a 16-bit charge-coupled-device (CCD) camera (see Figure 1) were used to image chilled aluminum cells that were, variously, empty or filled with ice or water to various thicknesses. Reference images of a 99-percent-reflectance standard were also acquired. The aluminum, water, ice, and reflectance-standard images were acquired in 21 wavelength bands, each about 10 nm wide, at nominal pass wavelengths from 850 to 1,050 nm. An independent set of data for verification of the spectral images was acquired by use of a point spectrometer.

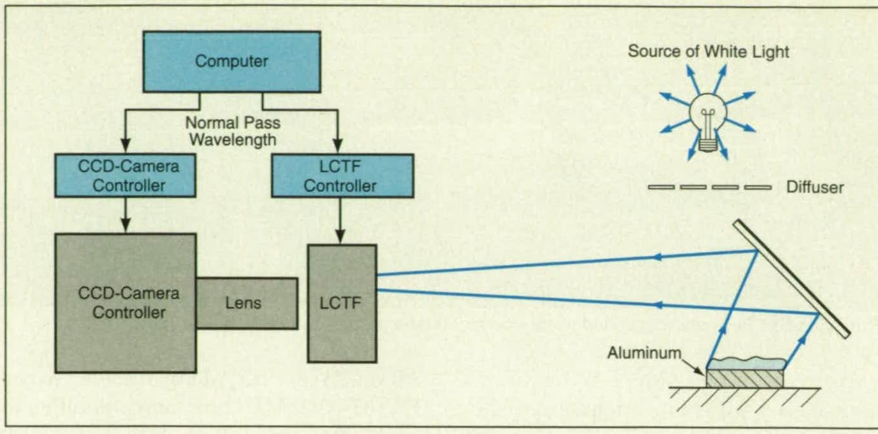

Figure 1. The **CCD Camera Looking Through the LCTF** acquires images of the same surface in 21 adjacent wavelength bands.

The spectral image data were corrected for CCD dark current and bias and converted to reflectance units, and regions of interest were chosen for determining the spatially averaged reflectance spectra. Some of the results are plotted in Figure 2, which illustrates how spectra can be used to distinguish between, and estimate thicknesses of, water and ice. The experiments revealed one shortcoming; namely, that specular reflection from the surface of interest can cause saturation in affected CCD pixels. Fortunately, saturated pixels can simply be excluded from processing of image data; this was done during the processing of image data in the experiments.

This work was done by Gregory Bearman, Abhijit Biswas, Thomas Chrien, Robert O. Green, and Peter Green of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at*** ***www.nasatech.com*** *under the Physical Sciences category. NPO-19929*

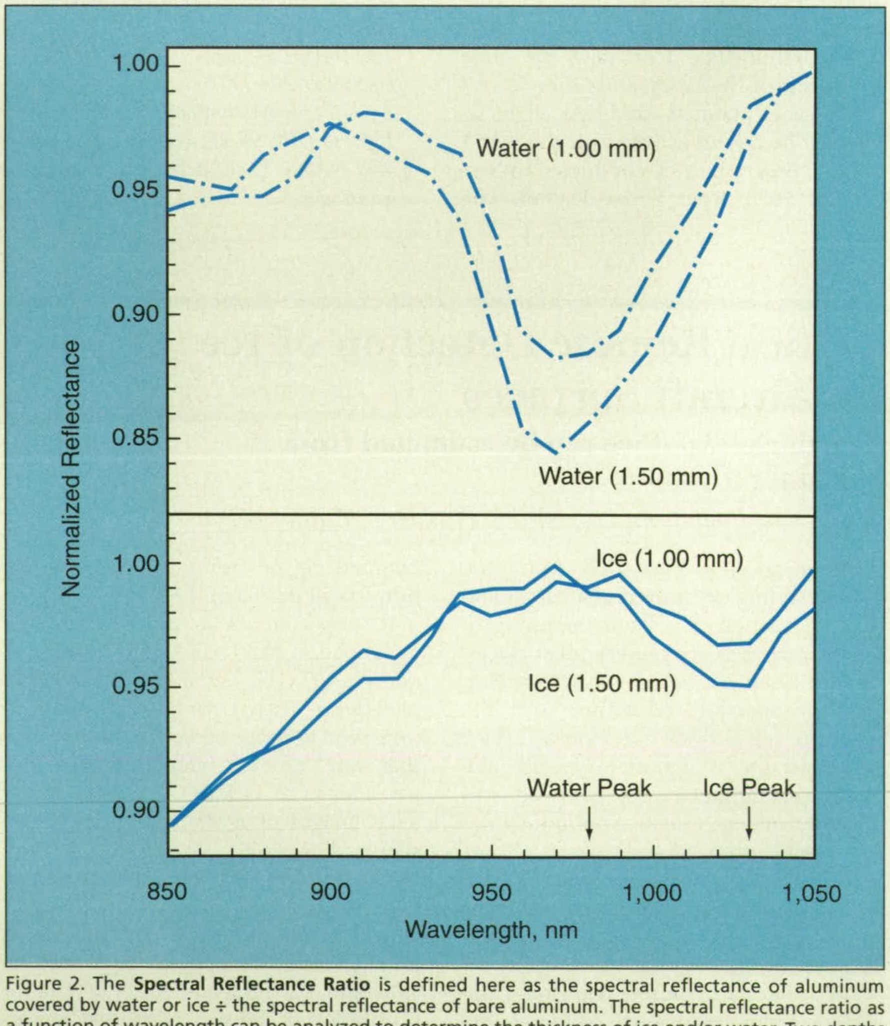

Figure 2. The **Spectral Reflectance Ratio** is defined here as the spectral reflectance of aluminum covered by water or ice ÷ the spectral reflectance of bare aluminum. The spectral reflectance ratio as a function of wavelength can be analyzed to determine the thickness of ice and/or water. Two depths of ice and water, 1 mm and 1.5 mm, were used.

September 1998

Electronics TECH BRIEFS

Photo Courtesy AMP Inc.

Creating Ethernet-based DAQ Data Acquisition Systems

There is a choice of methods for connecting instruments to computers.

Ethernet-based networks that use the TCP\IP protocol have become a standard method for connecting computers together for purposes of sharing data and distributed computing. Increasingly, engineers are also using these networks as convenient and powerful instrumentation buses. They match and often exceed the capabilities of traditional instrument buses in such areas as distance, speed, and availability of support tools.

National Instruments offers technologies enabling engineers to take advantage of networks to connect instruments to computers. These instruments can be of the traditional benchtop variety. They can also be of the virtual kind, in which the instrument consists of one or more plug-in data acquisition cards installed in a computer plus a software application that transforms the cards into the desired instrument and provides a user interface.

This article will describe five different techniques for creating networked data acquisition systems and assess their strengths and weaknesses. It will differentiate them with respect to the features a designer might want in a networked data acquisition system. The article assumes some familiarity with TCP/IP and Ethernet networking.

The term client is used to indicate the local computer, or station, not directly connected to the process being controlled or the test being performed. The term server is used to indicate the remote computer, or station, that is directly connected to some instrumentation (including plug-in data acquisition devices), which in turn are connected to the physical process or test. The term VI is used to refer to a subroutine or function written in the LabVIEW G programming language. VI stands for Virtual Instrument.

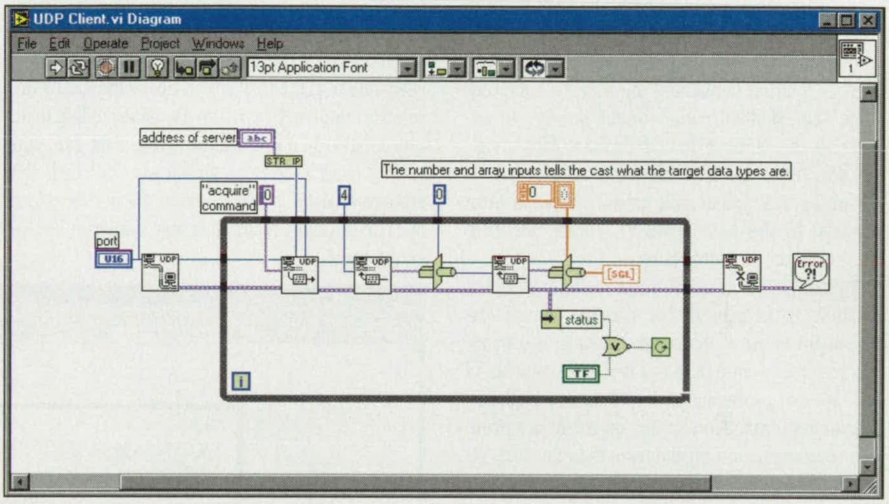

Figure 1. A simple UDP client application asking for and receiving data acquired remotely.

National Instruments offers five technologies for networked data acquisition systems:

- The GPIB-ENET adapter is a hardware solution that can connect any GPIB capable instrument to a network. Porting an existing application so that it can talk to and control an instrument via the network instead of directly via GPIB involves minimal work.
- The UDP and TCP libraries provide low-level networking communication primitives.
- A collection of techniques known as VIServer is bundled with LabVIEW and provides a powerful, high level tool for calling any LabVIEW VI remotely.
- The Internet Toolkits for LabVIEW and CVI are purchased as add-ons and provide tools for creating E-mail and FTP clients, web servers and more.
- The Remote Device Access (RDA) feature of NI-DAQ provides a completely seamless method of calling a DAQ VI or CVI Easy IO DAQ function remotely. NI-DAQ is the name for the computer-based data acquisition device driver software bundled with each board and used from LabVIEW or CVI.

The functionality the designer wishes to build into his system probably has the most influence on the choice of networking techniques. Does he want to extend the reach of an existing GPIB-based system? Does he want a remote station to perform computation or can it act strictly as a slave? Does he need a remote station to initiate communication or, again, can it act strictly as a slave? Will he have numerous clients that will merely need to see data or a single client that will have complete control over the remote stations? How secure does he need to make his system? Will it be exposed to the Internet or will it be on a private network? Does he need to build E-mail or FTP client services into his system?

Some of the techniques to be discussed are very general and low-level. You can accomplish a lot with these at the cost of greater complexity to your application. Other techniques are higher-level and more specialized. If they work for you using them will result in a simpler application. Still others offer very specific features such as E-mail or serving up data on the World Wide Web.

GPIB-ENET: This product simply extends the reach of standard GPIB-based benchtop instrumentation. You can access more GPIB devices at greater distances. There is some cost to overall throughput (50 kBytes/sec typical, although this will vary depending on your network configuration, traffic, etc.). Up to 14 GPIB devices can be attached to a single GPIB-ENET. Each GPIB-ENET box has its own IP address and thus acts like a node on your network. Your NI-488.2 software on your client computer translates standard GPIB commands to TCP messages that are sent to the GPIB-ENET where they

are converted back into GPIB commands for the instrument. If you want to access GPIB instruments at remote locations, this is an obvious choice.

UDP VIs in LabVIEW: The UDP VI library consists of just four VIs: UDP Open, Read, Write, and Close. The UDP Open VI requires only a port number, which both the client and server must use. The Open VI emits a connection ID wired into the other three. The UDP Read VI accepts the number of bytes to read and then blocks until that number is available or the timeout elapses. The Read VI also emits the port number and IP address of the computer that sent the message. This would allow you to implement a kind of security by creating your server-side application to only respond to messages from certain ports or addresses. The UDP Write VI accepts the input data, and also requires a port number and a network address, which can be supplied as a string containing the server's computer name (*i.e.*, domain name) or the server's IP address in the familiar dotted decimal form (*e.g.*, 123.456.789.012). The String to IP Address primitive in the TCP palette will convert it to the form required by the UDP Write VI. Finally, the UDP Close.vi closes the connection.

Typically, UDP is used in applications in which reliability is not critical. For example, an application might transmit informative data to a destination frequently enough that a few lost segments of data are not problematic. If TCP is not available, and you require the low calling overhead of a primitive communication mechanism, then the UDP VIs would be appropriate.

Since UDP is a general, low-level communication tool, it is possible to perform any type of remote operation that you wish. However, the greater the number of operations, the more complicated your command language will get. Figure 1 shows a simple UDP client application. Inside the while loop, a command (a '0') is sent to the server telling it to acquire some data. Next, the four-byte integer containing the size of the data acquired is read. Last, the data itself is read. A similar diagram would show the UDP server application that is the other half. Inside the while loop, the VI waits for the command (the '0') to acquire some data. The timeout for this UDP Read call has been set to 1 second (it defaults to 25 seconds).

TCP VIs in LabVIEW and C functions in CVI: The TCP protocol was created to provide the kind of reliability that UDP (and IP) does not. TCP is connection-based—that is, a connection between client and server must be established before any communication can occur. Also, TCP reports transmission errors and makes sure that all the packets arrive at the destination and are presented in the right order.

The TCP library, standard with both LabVIEW and CVI, follows a model similar to UDP with Open, Read, Write and Close being the basic operations. Both the port and IP address are specified when the connection is made. A higher level utility VI called TCP Listen is provided that asynchronously waits for a connection to appear before completing. Use this instead of the TCP Open.vi to simplify creation of the server-side program. The TCP Listen.vi also reports the port number and IP address of the computer making the connection. This enables you to implement some level of security by only responding to connections originating from certain ports and/or computers.

Developing a system using the TCP functions (or the UDP functions) gives you very general, low-level control. Both the client and server sides can initiate communication. The learning curve is small and the calling overhead low. As when using UDP, you must create a kind of command language so your client and server sides can "speak" to each other.

Since TCP is a general, low-level communication tool, it is possible to perform any type of remote operation that you wish. The greater the number of operations, the more complicated your command language will get.

The diagram for a simple TCP client VI would be very similar to the UDP client. Inside the loop it first sends a command (a '0') to the server telling to acquire data. Then it reads the 4-byte data size, converts it from a string to an integer and reads that amount of data. Figure 2 shows the server side of the TCP example. Again, it is very similar to its UDP counterpart.

access. Entering *.yourdomain.com gives everyone in yourdomain. com access. Entering a particular computer name gives or denies that one computer access. These access settings are persistent and come alive every time LabVIEW loads. If you don't want persistent access, you do it dynamically in a VI by setting the TCP/IP Access List property via a property node. Finally, the Edit>Preferences> Server: Exported VIs section is where you make VIs eligible for calling by a client. Entering * exports all VIs. A VI must be exported to be called remotely.

VIServer client applications are built on top of 6 primitives in the Application Control Palette. The Open Application Reference is the first thing called by the client. The application referred to is LabVIEW. After getting the application reference you get references to particular VIs by calling Open VI Reference. You must know the path to the VI and must also have a strictly typed Refnum to wire into the VI in order to use the Call By Reference Node.

Once you have the VI Reference you can wire it up to a Call By Reference node. The connector panel information in the strictly typed refnum is used to recreate the control and indicator terminals in the Call By Reference node. Wire up to these just as if you were using the actual VI it-

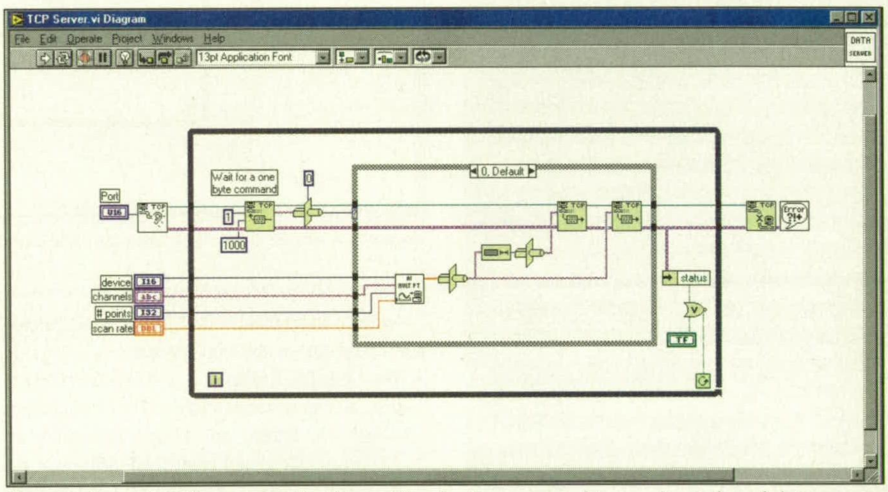

Figure 2. A simple TCP server application waiting for the command to acquire and send data.

self. If an indicator is not wired up on the client side Call By Reference.vi, the data is not sent over the network.

If the VI you are using from your client is not already loaded in memory on the server, it will load on the server when you Open a VI Reference to it. But, when loaded this way, the server LabVIEW will unload it when the client VI terminates.

The Call by Reference Node technique enables you to remotely call any VI you wish and thus perform any type of remote operation you wish. No command language need be invented as with the UDP or TCP techniques. There is more calling overhead with the Call by Reference Node technique than with either the UDP or TCP techniques. Your server can call VIs on your client in the same manner.

Figure 3 shows a diagram of a simple VIServer client. It does the minimum necessary to call a VI on the server. There is no corresponding server side program. None is needed as the server side configuration was done by editing the Preferences.

VIServer in LabVIEW: Two very different kinds of applications can be built using VIServer.vis, which are included with LabVIEW. One type of application is for programmatic control. Through use of the Property Node and Invoke Node, an application can load a VI, run the VI, control the front panel values and locations of the VI, and much more. The other type of application is for remote invocation of a VI. A VI on another computer elsewhere on a TCP/IP network can be executed by a VI running locally through use of the Call by Reference Node. It is this second type of application that is of interest here.

The server side of a networked application built with VIServer can be completely configured with the Edit>Preferences dialog box. Checking the TCP/IP protocol box in the Server: Configuration "turns on" the VIServer every time LabVIEW is launched. No VIs need to be running if this is checked. The Edit>Preferences>Server: TCP/IP Access selection is where you can give or withhold connection permissions. Entering * gives everyone

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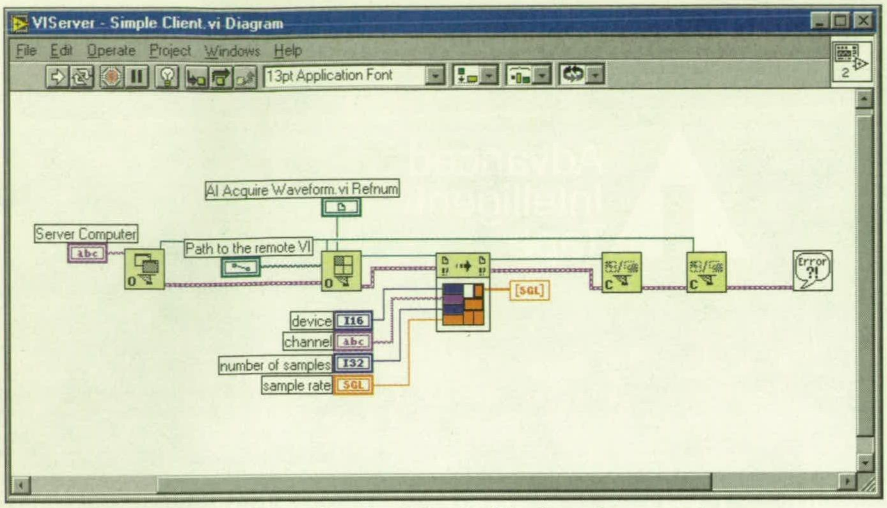


Figure 3. A simple VIServer client calling the AI Acquire Waveform.vi on a remote server.

Internet Toolkits for LabVIEW and CVI: If you need to incorporate E-mail or FTP client activities into your application or if you need to serve up data on the web or control a remote station from a browser, then one of these Internet toolkits will provide you with the tools you need.

The FTP functions enable to you build applications that can get and put text and binary files from and to FTP servers. In other words, you can create a full-featured FTP client. The E-mail functions enable to you write applications that can send electronic mail messages including file attachments to other users. A single function handles the sending of mail and attachments. You must know the name or IP address of an SMTP (Simple Mail Transfer Protocol) server to use them.

The most interesting area of these toolkits is their web server functions. The LabVIEW toolkit comes with a VI that instantly turns your computer into a web server. Launch LabVIEW, open a New VI and select from its menu Project>Internet Toolkit>Start HTTP Server. Once its running you can connect via a browser on another computer by simply typing the name or IP address of the server computer in the URL field of the browser. The page that comes up is in the LabVIEW\internet\home directory and is called index.htm. The page as shipped provides a way to browse through the Common Gateway Interface (CGI) examples. The One Shot DAQ example (LabVIEW\internet\home\cgi-bin\examples\daqcgi.vi) illustrates how to use a browser to initiate an acquisition on a remote station and return the data for display in the browser.

Remote Device Access in NI-DAQ: RDA is the easiest and fastest technique for acquiring data from, and sending data to, data acquisition devices over the network. LabVIEW DAQ VIs or CVI Easy IO functions are called from your client exactly the same way, whether you are using a device that is plugged into your client or into a remote station elsewhere on the network. The configuration of local devices occurs entirely on the client. The NI-DAQ Configuration Utility is used to connect to a remote station (here referred to as an RDA server) and select from among its devices. Once a remote device is selected, a local device number is assigned to it for use in local (client) programs. The programs then can run, unmodified, and use remote devices on the network. There is nothing to write for the server side. Only the RDA Server program needs to be running.

RDA is a part of the NI-DAQ data acquisition device driver and hence is included with every data acquisition device. It is by far the easiest of the techniques presented here to use. It is also fast, comparable to using TCP or UDP. However, its functionality is limited to performing only remote data acquisition operations. Also, since the RDA Server is currently unable to refuse requests from any client, you cannot implement the type of security that you can with the other techniques. Additionally, RDA servers cannot initiate communication to the client. They can only wait for a command and respond.

If you need to simply control data acquisition devices remotely, then the RDA technique is most suitable. If you need to remotely perform other activities besides data acquisition and are not too concerned about speed, then the Call by Reference technique of the LabVIEW VI Server is appropriate. If you need to perform other activities besides data acquisition, and speed is a concern, then the TCP technique is preferred. If you don't have TCP support you would use the UDP technique instead. Finally, if you need to incorporate E-mail for FTP client functions or to host data on the web or use a web browser on your client stations, then the Internet Toolkits are the way to go.

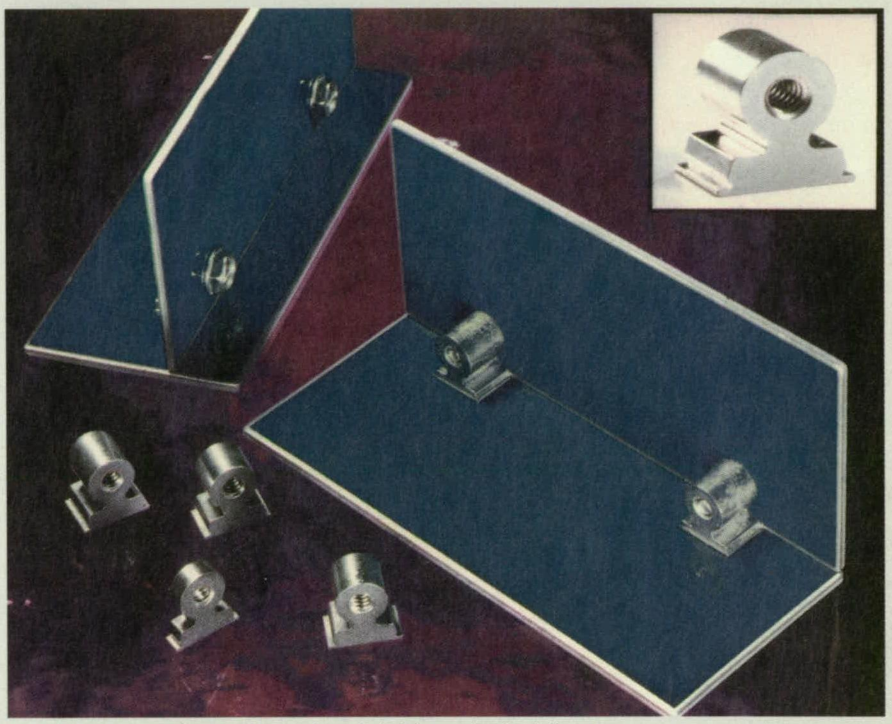
It is also good to remember that these techniques can be used together. A combination of RDA and Call by Reference VIServer is very powerful.

For more information, contact the author of this article, Timothy Hayles, Senior Group Manager for the DAQ Software Department at National Instruments, 11500 N. Mopac Expressway, Austin, TX 78759; (512) 794-0100; fax (512) 683-8411.

A New Angle for ELECTRONICS ASSEMBLIES

Design requirements for orthogonal chassis construction and front-panel attachment typically have been fulfilled by utilizing bent tabs and relief slots, brackets, and hardware. Each of these methods of producing right-angle assemblies has been known to exhibit inherent performance and/or production drawbacks. In electronic enclosures where EMI is a concern, the "holes" created when bent tabs are used can have a negative impact on desired shielding. Welding tabs forces an extra production step, and attendant plating/finish problems can occur.

Where right-angle brackets are used for mounting, a variety of additional necessary hardware includes attaching screws, washers, lockwashers, and nuts, which tend to hamper quick assembly and increase parts inventory. For these reasons, design engineers have looked for a more practical way to create right-angle attachment points, one that could also hold the promise of enhanced end-product integrity, reliability, and production efficiencies.



Penn Engineering's steel R'ANGLE threaded right-angle clinch fasteners.

Penn Engineering & Manufacturing Corp. has developed a unique solution utilizing self-clinching technology. Clinch-type PEM® R'ANGLE™ threaded and unthreaded fasteners for installation in thin steel or aluminum sheets can satisfy traditional and newly emerging right-angle mounting requirements without the need for tab cutouts, brackets, welding, extra hardware, or secondary tapping operations.

The general appeal of self-clinching fasteners for design engineers is their ability to provide strong threads in metal too thin to be tapped. During fastener installation in ductile materials, part of the metal sheet cold-flows into an undercut beneath the fastener's head, making the fastener an integral part of the sheet that will not loosen or fall out. This eliminates possible risk of damage to internal components or circuitry. A designed-in serrated clinching ring prevents the fastener from rotating once it is installed. The result is permanent installation with desired threads, high pushout and torque-out values, and considerably less in the way of required mounting hardware. These advantages multiply when the fastener further functions as a right-angle attachment point.

Saving Time and Hardware

A current electronics enclosure application involving R'ANGLE fasteners specifically illustrates the reasons behind the design and production interest in clinch fasteners and right-angle assemblies among design engineers. Two-piece enclosures housing delicate electronics for sensitive balances manufactured by Fillon Pichon USA, of East Providence, RI, utilize a total of six R'ANGLE Type RA™ (aluminum) unthreaded fasteners and compatible thread-forming screws. The amount of fastening hardware in each enclosure has now been reduced by half, per-unit assembly is now 15 minutes instead of one and a half hours, and two fabricating steps have been eliminated.

Each precision balance is an extruded metal chassis that would normally require taps to be punched and then bent in order to create right angles, according to RESH Inc., of Franklin, MA, a leading design firm consulted on the project. These punching and bending operations are no longer necessary.

A new method for creating right-angle attachment points in thin metal sheets can accelerate production and enhance product integrity and performance.

In this application, RESH fabricates the enclosures and installs the hardware before final assembly. The R'ANGLE fasteners, painted with a black finish for enhanced aesthetics, are pressed into 0.375-in. × 0.312-in. rectangular mounting holes. They clinch into the metal

for permanent installation, leaving the reverse side flush. The enclosures are then delivered complete with installed self-clinching hardware to Fillon Pichon, which installs the load sensors and electronic components and completes the final assembly.

Using R'ANGLE aluminum fasteners, all that is required are standard #6-32 thread-forming screws, which represents yet another application advantage: thread-forming screws do not generate the metal residue associated with thread-cutting screws, so they are widely preferred for use in electronic assemblies where metal chips cannot be tolerated.

In addition to aluminum unthreaded clinch fasteners, steel threaded right-angle clinch fasteners (Type RAS™) have been developed for a wider range of applications in steel or aluminum sheets as thin as 0.040 in. These steel R'ANGLE fasteners are made from powdered metal technology to achieve the part's unique shape and function; they accept standard machine screws.

More Applications

Other typical electronics-related applications demonstrate where right-angle clinch fasteners can be substituted to provide a cost-effective alternative to traditional assembly methods:

- In chassis construction: eliminating the "relief slots" that are necessary and visible from the outside of the box when using bent tabs; eliminating the "hole" when a tab is bent out of the center of the sheet to create a right-angle mounting tab; replacing right-angle brackets and the attaching screws, washers, lockwashers, and nuts with a single clinch fastener; and right-angle PC-board mounting;
- In front panels: providing a right-angle mount in the inside front panel while keeping the outside surface smooth for attachment of a plastic graphic overlay; and mounting the front or rear panel of an electronic box enclosure.

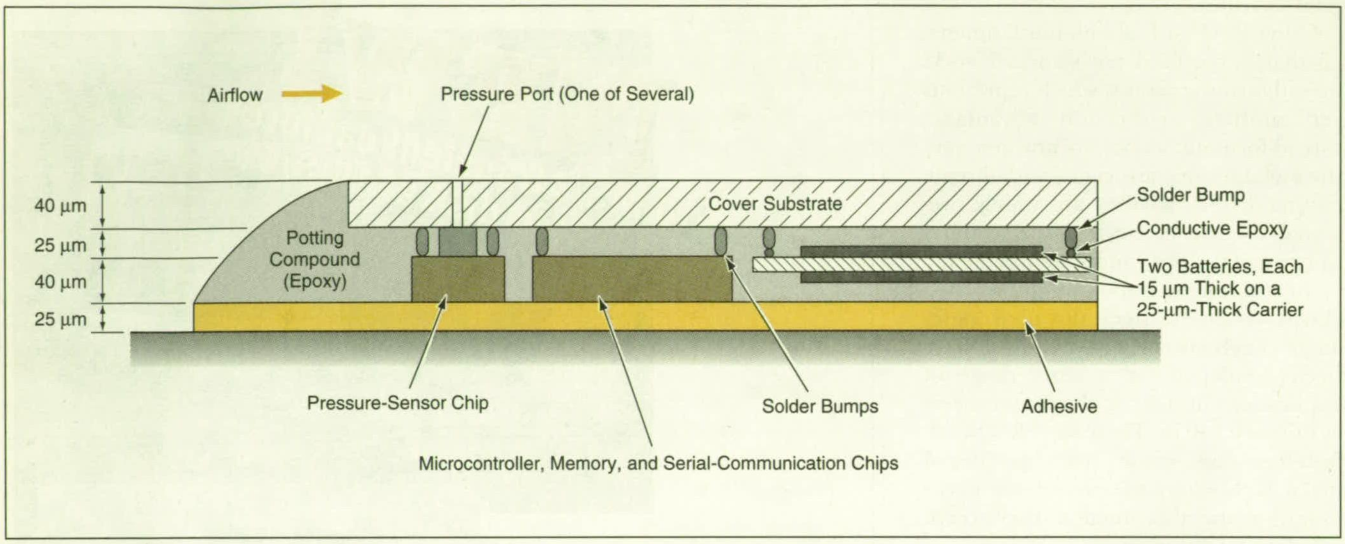
In general, right-angle clinch fasteners can replace bent tabs at edges of sheets, bent tabs in the middle of sheets, bent flanges, right-angle brackets, and tack welds. The result is more predictable designs and tighter design control, elimination of tab cutouts for better EMI/RFI shielding, material and assembly cost savings, reduction of loose hardware, more attractive panels, and elimination of welding.

For more information, contact Harold "Skip" Ross, Penn Engineering & Manufacturing Corp., Box 1000, Danboro, PA 18916; (800) 237-4736; fax: (215) 766-0143.

Ultrathin Packaging of Multiple Integrated-Circuit Chips

An instrument package is only slightly thicker than a piece of paper.

Lewis Research Center, Cleveland, Ohio



An **Instrument Package** that contains a pressure sensor and a data-acquisition system is so thin that it can be mounted on a surface exposed to a flow without appreciably perturbing the flow. For the sake of clarity, the thickness scale is greatly exaggerated in this view.

A process being developed for ultrathin packaging of multiple integrated-circuit chips and associated microelectromechanical components makes it possible to fabricate a minimally invasive pressure-measuring instrument to be used in characterizing a boundary-layer flow inside a turbomachine. Such an instrument must be thin enough not to appreciably perturb the flow; according to specifications supplied by NASA researchers, this means that the entire instrument package must be less than 5 mils (127 µm) thick. In comparison, a piece of copy paper is about 4 mils (102 µm) thick.

To achieve the needed capabilities for collection, storage, and processing of measurement data, it is necessary to integrate sensor, microcontroller, and memory chips into a single package. In addition to conforming to the stringent specification regarding overall thickness, the packaging is required to provide mechanical and electrical connections for all of the chips and for a rechargeable battery, protect the electronic components on the chips, hermetically seal the battery, expose a pressure-sensor diaphragm while preventing exposure of electronic circuits to the environment, provide means for charging the battery, and enable communication between the microcontroller and external data-processing equipment. Moreover, the thermal limits of the components must not be exceeded during the packaging process.

The packaging process, being developed to satisfy the foregoing requirements, is a highly modified flip-chip process that involves a novel extension of conventional packaging techniques.

The figure presents a simplified cross section of the finished instrument package adhesively bonded to a surface exposed to the flow to be measured, showing the battery and a few of the chips connected to the cover substrate. Note that the overall thickness of the package plus the adhesive is 130 µm, and could

be reduced to less than the maximum allowable thickness of 127 μm by thinning the adhesive layer to 22 μm or less.

This work was done by Daniel A. Pruzan of Nielsen Engineering & Research for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16545.

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Macro cells available for licensing include 8-, 10-, 12-, and dual 6-bit designs.

Sarnoff Corporation, Princeton, New Jersey

Sarnoff Corporation has announced the development of four new analog-to-digital (A/D) converter macro cells for embedding in CMOS designs in which high-precision, high-speed operation at low power is important. The 8-bit, 10-bit, 12-bit, and dual 6-bit designs are available for licensing by manufacturers who need A/D conversion modules as elements in new very large-scale integrated (VLSI) designs, or who want to upgrade their converters in existing designs.

The A/D converter macro cells have extensive applications in video, audio, and wireless signal processors. They are designed with low power requirements, small areas, and mainstream CMOS compatibility and scalability for ease of embedding into VLSI digital signal processing (DSP) chips.

Typical features and specifications include:

- for the dual 6-bit cell, speed of 60 MHz; power of 80 mW, 3.3 V; size of 1.3 × 0.9 mm; and process of 0.35 micron;
- for the 8-bit flash, speed of 60 MHz; power of 145 mW, 5.0 V; size of 1.3 × 1.2 mm; and process of 1.0 micron;
- for the 10-bit, speed of 40 MHz; power of 200 mW, 3.3 V; size of 2.7 × 4.0 mm; and process of 0.5 micron;
- for the 12-bit, speed of 20 MHz; power of 250 mW, 5.0 V; size of 6.4 × 6.4 mm; and process of 0.6 micron.

The dual 6-bit design and the 10- and 12-bit designs all use a patented successive approximation register architecture and MOS servo-loop circuitry to achieve high speed and high precision. The servo loop's auto-zero and auto-calibrate circuits function during each conversion cycle, eliminating the need for the usual precision component trimming or matching.

The 8-bit flash converter uses an "average interpolating" approach to reduce power requirements and boost speed. All four A/D converter macro blocks accept TTL inputs and provide CMOS or TTL outputs. They also feature tri-state output buffers with enable. The converters combine precision and performance without the complexity of bipolar or BiCMOS technology.

This work was done by Bill Mayweather, director of the Systems and Design Laboratory, and his colleagues at the **Sarnoff Corporation**. *For further information, contact Tom Lento at the Sarnoff Corp., CN 5300, Princeton, NJ 08543; (609) 734-3178; fax (609) 734-2040; tlento@sarnoff.com.*

Sensor Combines Technologies to Achieve Application Versatility

The unique sensor's advantages include elimination of external limit switches, potentiometers, and the like, and their associated labor costs.

Spectrol Electronics Corporation, Ontario, California

Figure 1. The **DigiSense** sensor.

By combining patented digital Silver-in-Glass® and analog conductive plastic technologies in a single environmentally sealed unibody package, Spectrol Electronics' DigiSense™ provides thousands of application-specific multifunction outputs (Figure 1). The conductive plastic potentiometric output furnishes the analog signal and absolute position, while the Silver-in-Glass digital logic output provides limit-switch functions, logic signals, and zone logic.

Analog and digital circuits are completely isolated, providing redundant signal capability in the same package. Sensor users are offered complete flexibility to design the element to match their functional requirements. They can also select optional shaft configurations, output terminals, electrical angle and logic switch points.

The unique sensor can be used as an actuator, feedback position device, or both. When used as an actuator, DigiSense sets the speed, height, and position of a particular mechanical action. Used as a feedback sensor, DigiSense transduces the mechanical angle into a voltage signal to complete a control loop. In most closed-loop control circuits, there are both actuator and feedback demands.

Thick-film Silver-in-Glass technology not only adds physical strength to the sensor design but also minimizes the step-height differential between the conductor and the insulator surface. Instead of a "bump-up" contact intersection on the order of 25-35 microns, as found in designs utilizing composite

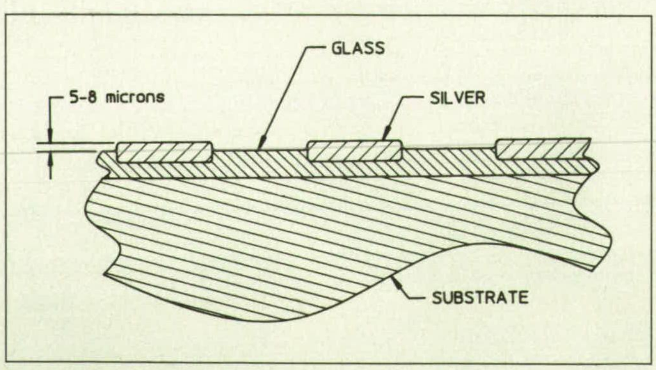


Figure 2. The design minimizes the **Step-Height Differential** between the conductor and the insulator surface.

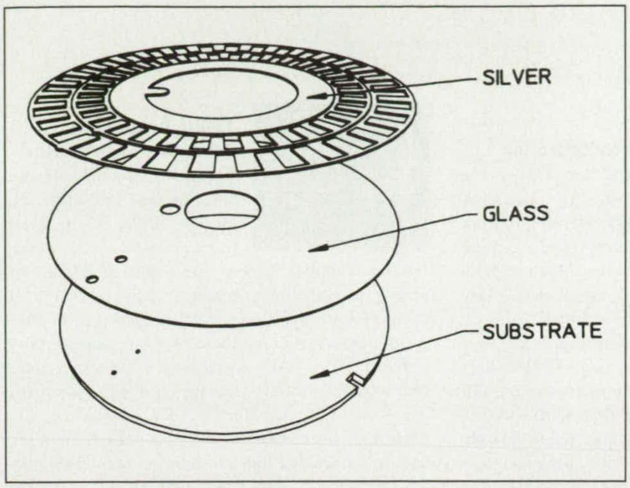


Figure 3. **Silver-in-Glass Technology** involves the deposition of a smooth thick-film glass over the surface of an alumina ceramic substrate.

board with copper foil etching, contacts must only "climb up" between 5 and 8 microns at each contact point as the shaft is rotated (Figure 2). The relatively flat, smooth wiping surface helps eliminate wear, electrical noise, and dimensional instability, which can cause switching inaccuracies. Single-track sensors utilizing Silver-in-Glass technology have a current capacity up to 100 mA. Rotational life exceeds 25 million cycles. Problems associated with vibration, shock, and contact bounce are counteracted by multifingered precious-metal "hoe"-shaped contacts.

The process involves the deposition of a smooth thick-film glass over the entire surface of an alumina ceramic substrate (Figure 3). After the glass layer has been fused to the substrate, a conductor pattern of palladium silver is printed on top of the glass. During kiln firing, the silver conductor sinks into the glass surface, forming a very smooth switching surface.

Conductive plastic technology, patented by Spectrol, is a process formulated to survive the 300 million dither cycles that the Ford Motor Company set as its benchmark for most under-the-hood automotive sensors. Temperature range is -40 to 150 °C. The process provides an output signal that is very smooth, exhibits extremely low noise, and has virtually infinite resolution.

This product was designed by an engineering team at **Spectrol Electronics Corporation**, *4051 Greystone Drive, Ontario, California 91761. For more information, call Brad Canfield at (800) 624-8902; E-mail: spectrol@spectrol.com.*

Signal Preprocessor for Determining Time of Arrival

John F. Kennedy Space Center, Florida

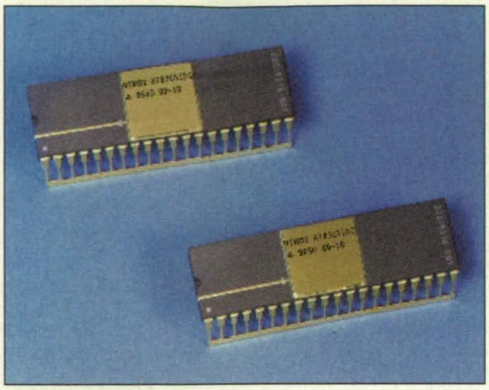
A proposed analog/digital circuit would improve the accuracy of determining the time of occurrence of a peak in an analog waveform. In the past, the time of occurrence of the peak was determined by comparing the magnitude of digital data samples. The time or clock pulse associated with the peak magnitude was taken as the time of occurrence of the peak of the waveform. The new technique saves a series of data samples (7) prior to and after the sample with the largest amplitude. The set of data samples is saved and is used with curve-fitting equations to estimate the time of the peak of the waveform. This can be done because of the deterministic character of the waveforms. This technique allows the time of occurrence of the peak of the waveform to be determined with greater resolution than can be obtained by simply sampling the data and looking for the peak. This technique has applications in systems where it is desirable to determine the relative time between waveforms. The Lightning Detection and Ranging (LDAR) system at KSC uses the differences in the time of arrival of lightning waveforms at seven sites, to locate lightning sources. The technique described is being implemented in the improved system to increase accuracy.

This work was done by Carl L. Lennon of **Kennedy Space Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center; (407) 867-2544. Refer to KSC-11805.

NEW PRODUCTS

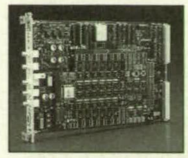
PRODUCT OF THE MONTH



High-Temperature Microcontroller

Honeywell, Plymouth, MN, introduces the high-temperature Model 83C51 microcontroller to its line of HTMOS™ electronic products. The new component is designed for applications with extremely wide operating temperature ranges, such as down-hole oil wells, aerospace, turbine engines, and industrial control. A monolithic 8-bit microcontroller, it supports operating frequencies in excess of 16 MHz over the full -55 to +225 °C temperature range, with reduced performance operation up to +300 °C. It uses the standard MCS-51 instruction set optimized for control applications. Honeywell says the pretested part will last tens of thousands of hours at 225 °C.

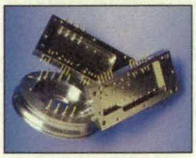
For More Information Circle No. 761



12-Bit Arbitrary Waveform Generator

Racal Instruments, Irvine, CA, makes available the Model 3162A 12-bit waveform generator, which combines a 500-MHz update rate, external digital and analog modulation, frequency agility, a built-in 1-ppm reference oscillator, and 1 megasample of waveform memory. Among the software support supplied is Racal's WaveCAD, a graphical waveform generation/control software package, and a LabVIEW driver. Racal calls the Model 3162A's 500-MS/s sampling rate the fastest for a 12-bit generator in the industry. Gigabit Ethernet, telecom standards from DS-1 to SONET/SDH, radar, GPS, HDTV, ECM, and avionics can be simulated.

For More Information Circle No. 762



Filtered Microcircuit Packages

Spectrum Control, Erie, PA, can develop and supply customer-specific turnkey soldered microcircuit assemblies in a wide variety of complex housing designs and EMI or DC feedthrough filter configurations. Housing material options include Kovar, aluminum, copper, titanium, and copper alloys. Filter circuits include C, LC, and high-performance Pi, and connectors offered are RF, SMA, bias pins, and snap-ins. A variety of Spectrum Control capacitors are available for the package, providing insertion loss from 1 MHz to 18 GHz. Capacitor voltage rating is 200 VDC, current rating 5 A, and temperature rating from -55 to +125 °C.

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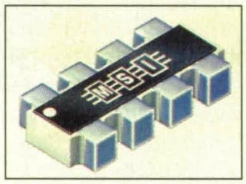

Surface-Mount Resistor Networks

The SMR series of resistor networks from the Thick Film Division of Mini-Systems Inc., North Attleboro, MA, has a standard value range of 2-10MΩ in isolated or common bussed configurations, with tolerances to 0.5 percent. Designed for fine-pitch surface-mount applications, these resistors feature lead pitch of 0.031" (0.8 mm), and are available in 4- to 16-pinout styles. The company says the protruding five-sided nickel barrier terminations enhance solder attachment and inspection. The footprint for a SMR 8 four-resistor network is a 1206 case size.

For More Information Circle No. 764

Serial Input Digital-to-Analog Converter

From Burr-Brown Corp., Tucson, AZ, comes the DAC7611, a serial-input digital-to-analog converter in a small 8-lead SOIC package or 8-pin plastic DIP package. Using the company's low-voltage 2-micron BiCMOS process technology, the converter features low power consumption of 2.5 mW and single +5-V supply operation. It contains an input shift register, latch, 4.095 reference, DAC, and high-speed rail-to-rail output amplifier. The company says its synchronous serial interface is compatible with many DSPs and microcontrollers.

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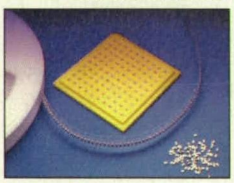

Surface-Mount Ceramic Capacitors

American Technical Ceramics, Huntington Station, NY, offers the 500 Series broadband microwave surface-mount capacitors. The company describes them as rugged, surface-mountable devices with very high self-resonant frequencies in values up to 10 pF. The capacitors have first parallel resonant (FPR) frequencies exceeding 35 GHz for values of 0.1 to 2.2 pF and FPR exceeding 20 GHz for values up to 10 pF, making them suited for broadband DC blocking/RF coupling. The devices have a stable NPO temperature characteristic and are laser marked.

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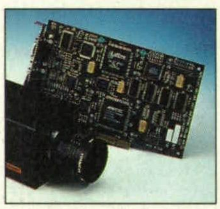

Fiber-Compatible PCI Board

Wintriss Engineering Corp., San Diego, CA, says that the fiber-compatible version of its PCIHOTLink high-speed host interface board significantly extends the distance over which digital serial data may be transmitted and received. Designed for use with 50-μm multimode optical fiber, the board allows HOTLink-based peripherals to communicate bidirectional data to a PC-based host over distances of up to 500 meters. The on-board Cypress HOTLink chipset performs parallel-to-serial-to-parallel conversion using the FC-1 8B/10B encoding/decoding scheme.

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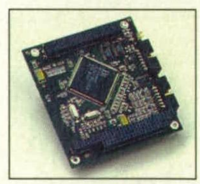
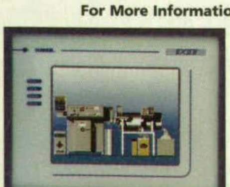


Framegrabber Boards for Industrial Image Capture

The Model 311 framegrabber for the PC/104+ bus from Sensoray Co., Tigard, OR, is the latest in the company's SX-11 Series of image boards, joining the Model 611 for PCI and the Model 711 for CompactPCI. Like the others, the Model 311 captures analog color and monochrome images in real time (30 fps) and converts to digital format for computerized image processing and display. All SX-11 Series framegrabbers take camera inputs from NTSC, RS-70, PAL, SECAM, and CCIR. Up to three cameras may be connected to the board. It supports several digital formats, including RGB24 and Y8.

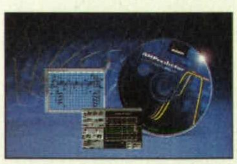
For More Information Circle No. 768



Passive Color Touchscreen

Exor Electronic R&D, Wellington, FL, introduces a 5.6-in. (diagonal) passive color touchscreen operator interface. The Model ECT-16 features full 16-color graphics capability with three ports for PLC, printer, and bus networks. The E-16 is programmed with Windows-based software, as are all Exor models, with over120 drivers for communication with an array of PLCs, motion controllers, and intelligent devices. A simple module connects the ECT-16 to PROFIBUS DP, DeviceNet, and other networks. Encased in a rugged housing, the interface is suited for harsh industrial environments, the company says.

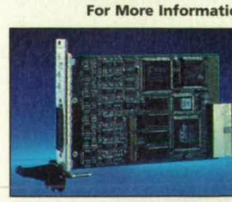
For More Information Circle No. 769



Signal Integrity Analysis Software

New from AMP Inc., Harrisburg, PA, is AMPredictor™ SIA 3.0 software, which the company calls an integrated suite of simulation and interface tools that enables digital system design engineers to perform complete-system multiboard critical-net simulations. Version 3.0's central interactive work area has a new interface that AMP says provides greater ease of use and enhanced functionality, including direct linkage to AMPSPICE™ Circuit Simulator Software, a revised graphical user interface that provides functionality for measuring rise and fall times, evaluating crosstalk, setting noise margins, and more.

For More Information Circle No. 770



Interface Board for cPCI Backplanes

SBS Avionics Technologies, Albuquerque, NM, announces its ARINC 429 interface board for cPCI backplanes, adding to the product family that already embraces ISA, PC/104, PCI, PCMCIA, and VMEbus. It provides the user with 8 highly programmable ARINC channels over the backplane. Each channel is software-configurable for transmit or receive, high- or low-speed (12.5 or 100 kB/s), and ARINC 429 or 575 protocol requirements. An on-board DSP controls the flexible data structures, triggers, interrupts, time-stamping, and data communications on the 429 bus.

For More Information Circle No. 771

Information Sciences

Robust Aeroservoelastic-Stability Margins

Structural dynamics of the closed-loop system are analyzed.

Dryden Flight Research Center, Edwards, California

In aeroservoelastic (ASE)-stability analysis, one considers the coupling of the aerodynamic, inertial, structural, actuation, and control-system elements of the dynamics of an aircraft. The closed-loop interactions of these elements can introduce unexpected instabilities in flight if the analytical model used for synthesis and analysis is not accurate. Measures of allowable flight-condition variations, called "stability margins," should be computed to indicate the range of velocities and altitudes within which the aircraft can safely operate.

An approach known as the μ method was recently introduced for analyzing stability margins of open-loop flexible aircraft models. [The μ method was described in "Characterizing Worst-Case Flutter Margins From Flight Data" (DRC-97-03), *NASA Tech Briefs*, Vol. 21, No. 4 (April 1997), page 62.] This method is based on a formal mathematical concept of robustness that guarantees a level of modeling errors to which the aircraft is robustly stable. A realistic representation of errors can be formulated by describing differences between predicted responses and measured flight data. The structured singular value, μ, is used to compute a margin that is robust to these errors.

The μ method has now been extended to enable the evaluation of aeroservoelastic-stability margins of closed-loop, flexible aircraft models. For a given aircraft, uncertainty operators are introduced into the analysis to describe errors in the structural and aerodynamical models along with errors in the sensor and actuator models. The resulting stability margins are superior to such traditional measures as gain and phase margins, which cannot be easily interpreted as flight-condition information. Also, the extended μ method can be used to simultaneously compute closed-loop ASE stability margins and open-loop flutter stability margins.

Flight data are easily incorporated into the stability analysis in this method. Uncertainty operators are derived by model validation to ensure that the dynamics observed in the data are repre-

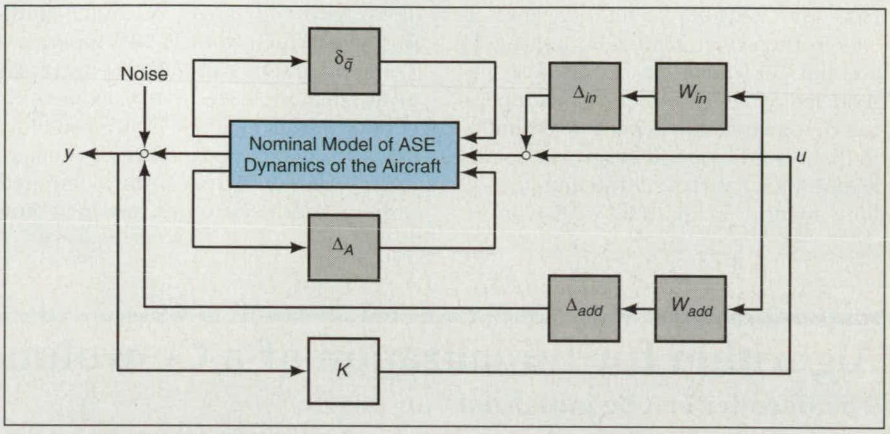


Figure 1. The **Uncertainty Operators** described in the text are incorporated into the mathematical model along with the nominal dynamical model of the aircraft, with a feedback-control gain matrix K, and with uncertainty-weighting operators W_{add} and W_{in}.

F/A-18 HARV

Mach Number	Altitude, kft	Γ_{nom}, lb./ft.^{2}	Γ_{rob}, lb./ft.^{2}
0.3	30	−268	−4
0.7	30	−2,710	−262
0.3	10	−757	−17
0.7	10	−3,153	−422

Figure 2. **Nominal and Robust Stability Margins** — Γ_{nom} and Γ_{rob}, respectively — were calculated for closed-loop operation of the F/A-18 HARV equipped with a thrust-vectoring control subsystem.

sented in a robust mathematical model. The stability-margin parameter, μ, is robust to the measured variations associated with the uncertainty operators. In this sense, the stability margins are worst-case margins with respect to the flight data.

In the extended μ method, an uncertainty description, as shown in Figure 1, is formulated for the mathematical model of a given aircraft. This description includes Δ_A to account for errors in the modal parameters of the state matrix, Δ_{in} to account for multiplicative errors in the actuator models, and Δ_{add} to account for remaining errors and unmodeled dynamics. An additional operator, $\delta_{\bar{q}}$ is included to represent variations in flight condition and ensure the model is robust to all variations less than the stability margin. Magnitudes of the uncertainty operators are computed to account for errors observed between predicted responses of the model and measured flight data from accelerometers.

In an application of the foregoing methodology, ASE-stability margins were computed for the F/A-18 High Alpha Research Vehicle (HARV). There had been concern about the closed-loop stability margins of this aircraft operating with high angles of attack at high altitudes. The ASE stability margins are given in Figure 2 for the aircraft model at the extreme ranges of flight conditions in which the HARV operates. These margins are the biggest decreases in dynamic pressures that may be safely considered before an ASE instability can be encountered. The parameters Γ_{nom} are the stability margins computed without consideration of any modeling errors or uncertainties. These margins indicate that the nearest unstable flight condition for the nominal model is quite far from the flight envelope. The parameters Γ_{rob} are the stability margins computed with consideration for errors and uncertainties. These margins are considerably smaller than the nominal margins and indicate that the nearest instability may actually lie quite close to the flight envelope. In particular, the model at mach 0.3 and altitude of 30,000 ft (9.1 km) has very little robustness to the errors that are observed from the flight data.

This work was done by Martin Brenner of **Dryden Flight Research Center** *and Rick Lind of NRC. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. DRC-98-37*

Algorithm for Initialization of a Convolutional Decoder

The decoder can be initialized "on the fly."

NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm effects rapid initialization of a convolutional decoder. This algorithm can be applied "on the fly"; that is while the decoder is receiving a stream of convolutionally encoded data. In comparison with other means of initialization, this algorithm is simpler, and it can be embedded in decoder hardware at relatively low cost.

"Initialization" in this context denotes establishment of the correct initial code state of the decoder. Standard convolutional decoding requires setting the decoder in a known initial state consistent with the state of the encoder; without initialization, the decoder cannot reconstruct the original uncoded data stream.

The algorithm is best described via the example illustrated in Figure 1, which shows the logic diagram of a coder/decoder pair that implements a binary convolutional code of length 7½. The encoder processes the input data stream into two encoded data streams. A notable property of convolutional encoding is that the initial state of the encoder determines the encoder outputs. In this case, there are 2^6 possible initial states, and it is therefore reasonable to assume that an input data stream could be mapped to any one of as many as 2^6 unique pairs of encoded data streams. In a typical application, the encoder registers are preloaded with some known bit pattern to restrict the encoder to one of the 2^6 possibilities.

The algorithm is based on the discovery that the pattern used to initialize the decoder can be calculated in real-time from the encoded data. The two encoded data streams are fed to two input terminals of the decoder, which processes these streams to produce two output streams. Provided that the decoder is initialized by use of the same bit pattern that was preloaded into the decoder, both output bit streams are forced to remain the same during the first six decoder shift cycles. Thereafter, if the decoder has been initialized

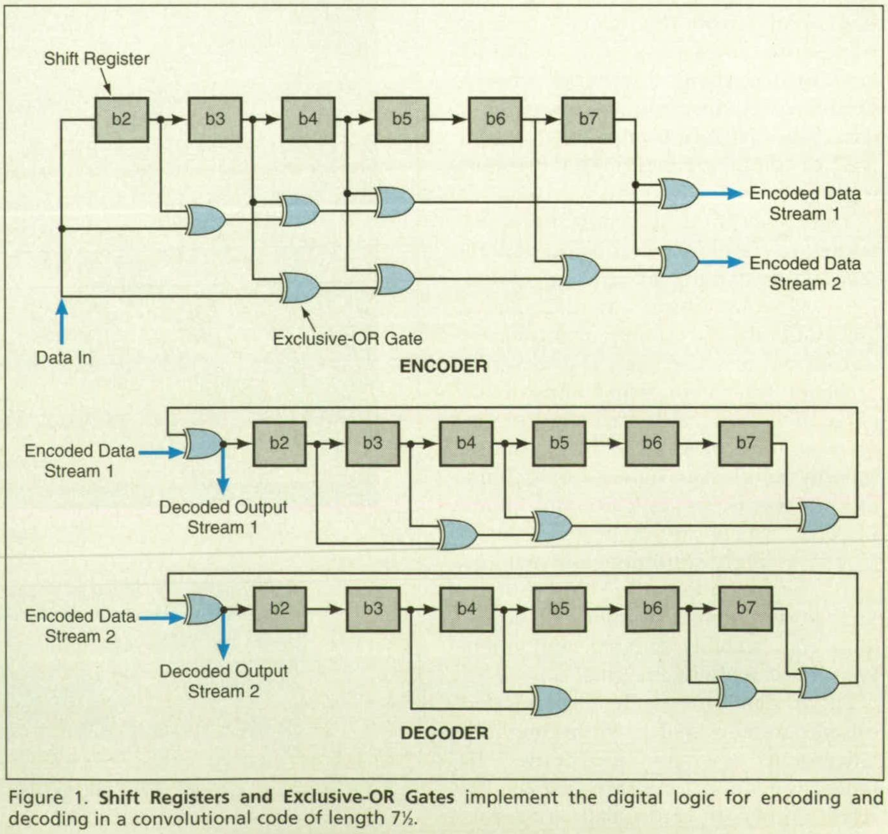


Figure 1. **Shift Registers and Exclusive-OR Gates** implement the digital logic for encoding and decoding in a convolutional code of length 7½.

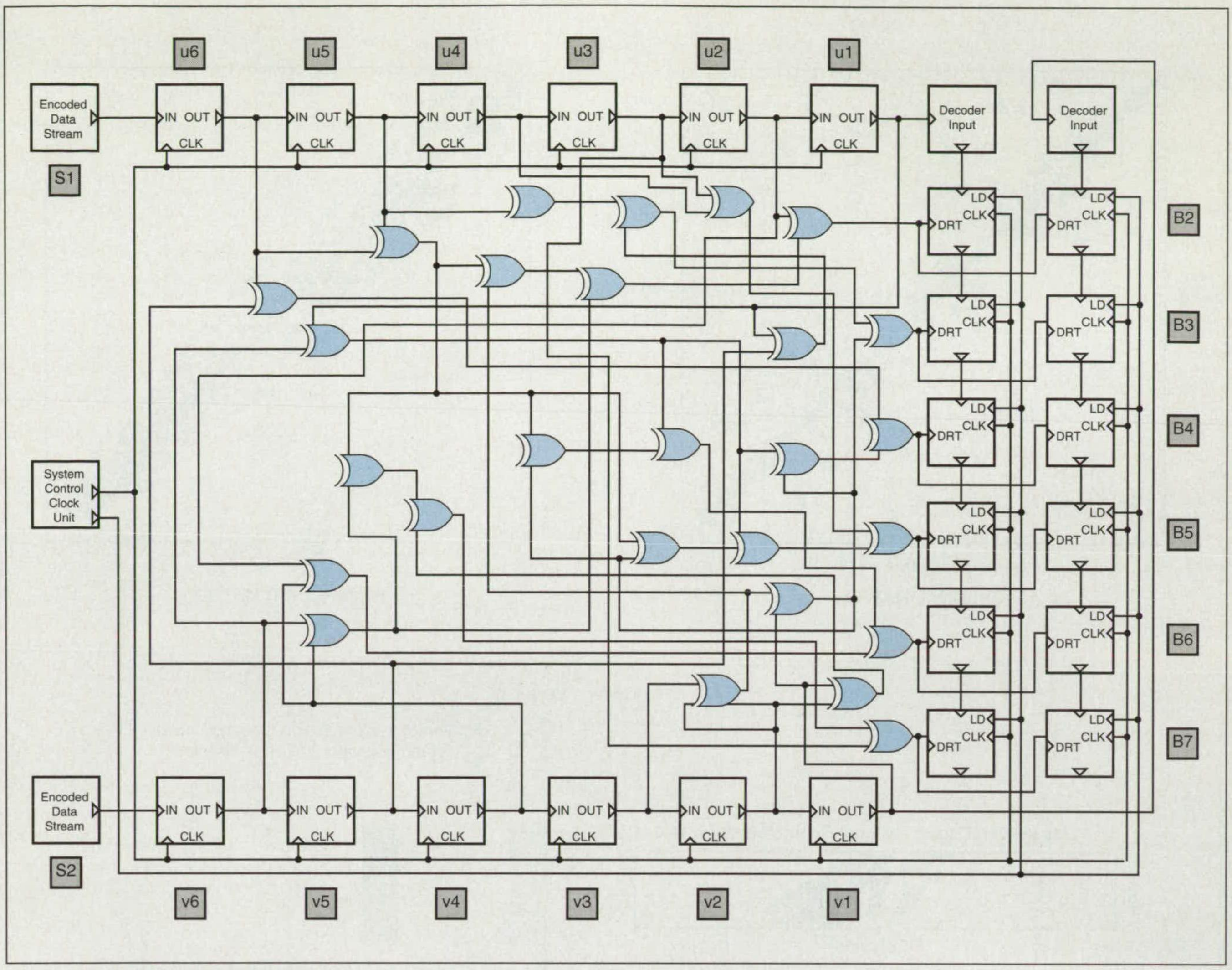


Figure 2. The **Initialization Algorithm** can easily be implemented in hardware.

correctly, both output streams should continue to be identical and to contain the original data in uncoded form. If the decoder has not been initialized correctly, then typically the decoder output bit streams begin to differ.

The algorithm (see Figure 2) can be started at any time during reception of the encoded data streams. From the first six pairs of encoded bits following its start, the algorithm calculates what the initial state of the decoder should have been, then it tests the calculated initial state for alignment of the two decoder output streams as described above. If the calculation of the initial decoder state has been successful, the decoder is synchronized and the algorithm is terminated. If the calculation has not been successful, then the alignment of the encoded data streams at the input of the decoder is shifted and another decoding run is made in the effort to achieve synchronization. This procedure is repeated until synchronization is achieved or until an error is detected.

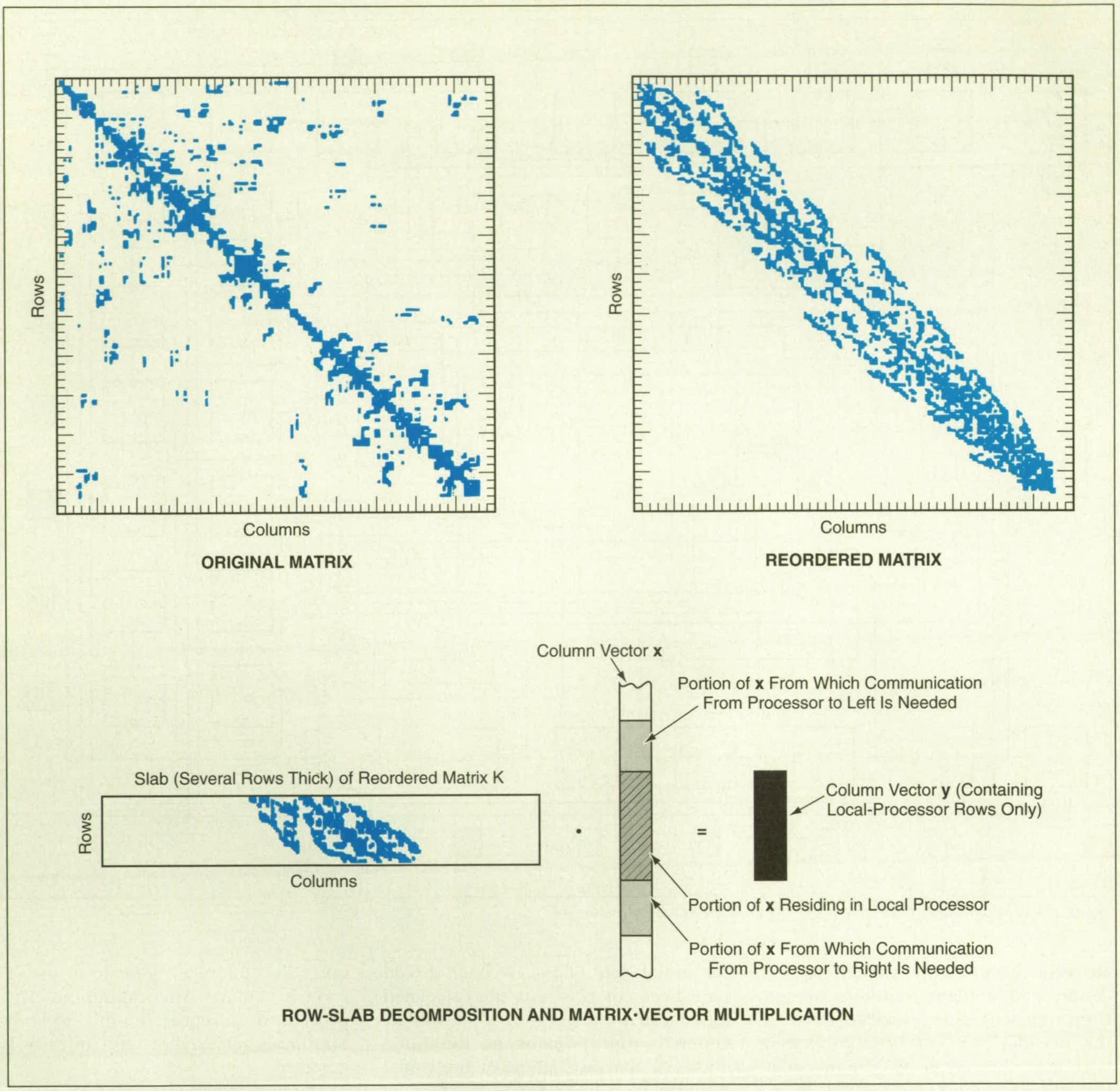
This work was done by Frank M. Loya of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. NPO-19776*

Improved Parallel Computation of Electromagnetic Scattering

Solutions can be computed on unstructured grids, without need for traditional mesh-partitioning algorithms.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of parallel computation of the electromagnetic-scattering characteristics of complexly shaped objects has been devised. This method belongs to a class of methods that involve the finite-element solution of Maxwell's equations on unstructured grids. ("Unstructured grids" in this context does not signify grids that lack structure; instead, it is a specialized term for grids with arbitrarily specified, complex, and/or irregular structures.) As explained below, the present method effects a simplification (relative to the older methods in the same class) in the



The **Nonzero Elements of the Sparse Matrix** are indicated by the colored spots. The matrix is reordered for minimum bandwidth, then subjected to the row-slab decomposition to enhance the efficiency of the parallel computation of the matrix·vector product **Kx = y**.

use of parallel computers, and involves an algorithm that is scalable in the sense that it is readily useable on large, massively parallel computers.

A finite-element mathematical model is needed to represent a typical electromagnetic-scattering structure that includes components made of various electromagnetically penetrable (e.g., dielectric) and/or impenetrable (electrically conductive) materials. An unstructured grid is needed to represent the complexity of the geometry of such a structure and its components. In the present method as in the other methods of the same class, the computational grid or mesh for a given problem must be truncated at a surface that surrounds the scattering structure at a suitable distance. The surface must be chosen consistently with the need to both maintain accuracy of the computed electromagnetic field and limit the meshed volume of free space. Maxwell's equations for the electromagnetic field are put in three-dimensional Helmholtz wave-equation form and solved on the mesh by a coupled finite-element/integral-equation technique.

The specific integral-equation formulation is of a boundary-element type. This formulation results in efficient and accurate truncation of the computational domain. A system of equations in partitioned-matrix·partitioned-vector form results from the combination of (1) finite-element discretization of the volume in and around the scattering structure and (2) integral-equation discretization of the surface. The system of equations is solved by a combination of (1) an iterative sparse-matrix-equation-solving subalgorithm and (2) a dense-matrix-factorization subalgorithm. The assembly and solution of the matrix equation and the computation of observable quantities are all accomplished in parallel, using various numbers of processors at various stages of the calculation.

A common feature of the older methods is the need for mesh-partitioning algorithms to distribute the unstructured mesh and the sparse matrix entries

among the available processors. This need arises from the distributed-memory architecture of typical parallel computers and the consequent lack of direct access, by every processor, to all the mesh and matrix data. In the present method, one does not explicitly partition the mesh; instead, one emphasizes decomposition of the sparse matrix entries among the processors, and such mesh partitioning as happens to occur becomes merely incidental to this decomposition. The choice of a specific decomposition is guided by recognition that what one needs to compute efficiently at each step of the iterative subalgorithm is the inner product of a sparse matrix and a dense vector.

The chosen decomposition is of a row-slab type. The figure illustrates aspects of the row-slab decomposition for an example problem. The top left part of the figure shows the original structure of the sparse matrix. The top right part of the figure shows the structure of the matrix as reordered for minimum bandwidth in preparation for the row-slab decomposition and the resulting matrix·vector multiplication $\mathbf{Kx} = \mathbf{y}$. Each processor handles one slab. Because of the minimum-bandwidth reordering, the minimum and maximum column indices of each slab are known. If the row indices of that piece of the dense vector $\mathbf{x}$ that is local to this processor contain the range from the minimum to the maximum column index for this slab, then the multiplication can be done purely locally, and the corresponding part of the product vector $\mathbf{y}$ will be purely local. In general, the column indices range beyond the local row indices; this gives rise to a need for a communication step to obtain the adjacent portions of $\mathbf{x}$ that are not local to this processor. This communication step involves data from a few processors to the left and right. The number of processors communicating data depends on the row bandwidth of the slab and the number of processors in use. Overall, the row-slab decomposition strikes a balance among (1) nearly perfect balance of data and computational load among processors, (2) minimal albeit suboptimal communication of data in the matrix·vector multiplication, and (3) scalability to larger problems on greater numbers of processors.

This work was done by Tom Cwik, Cinzia Zuffada, and Vahraz Jamnejad of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

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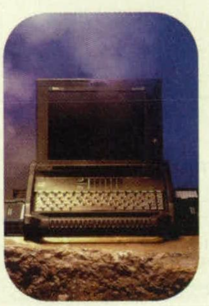
New on the MARKET

Bellows for Flexible Seals

Servometer Corp., Cedar Grove, NJ, offers a line of 16 electrodeposited nickel bellows designed for dynamic sealing applications requiring reliability and long life. Servometer® bellows can be designed for a variety of stroke and pressure combinations and for temperatures from -423° F to +350° F. The bellows can be soldered or E-B welded to custom end pieces. The company also can manufacture the complete bellows assembly. **Circle No. 713**

Portable Block Calibrators

The OMEGA® CL700A Series of block calibrators from Omega Engineering, Stamford, CT, are CE-approved and housed in a rugged metal case designed for field use. Features include an RS-232 computer interface for data and program transfer or real-time control; high stability for certifying temperature sensors and hydraulic thermostats; fast settling time for rapid testing; an interchangeable insert format; efficient heat-up and cool-down times; and Year-2000 compliance. **Circle No. 714**



Rugged Notebook Computers

FieldWorks, Eden Prairie, MN, offers the FW5000 Series II Field WorkStation® rugged notebook computers, which provide up to four module bays for user configurations. The Model FW5200P has a 200-MHz Pentium processor; the FW5166P has a 166-MHz Pentium processor; and the FW5133P has a 133-MHz Pentium processor. Standard features include internal 1.3 GB, 100G operating hard drive; 16 MB RAM, upgradeable to 64 MB; 512k synchronized pipeline burst CACHE; 10.4" 800 x 600 color active display; 3.5" removable floppy disk module; 4 MB DRAM for video; PCI bus; and 16-bit stereo sound with two integrated speakers. Two module bays house removable hard drives and PCMCIA modules, and the other two house a CD-ROM drive, a floppy disk drive, or batteries. **Circle No. 723**

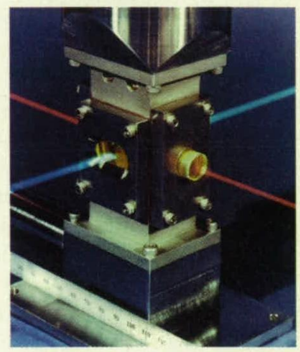
Digital Oscilloscope/ Analyzer

The Integra 40 four-channel digital oscilloscope/transient analyzer from Nicolet Technologies, Madison, WI, is designed for high dynamic range physical measurements. It utilizes four 20-MS/s 12-bit digitizers, an internal 3.5" floppy-disk drive, and a 500-MB hard disk. Memory lengths to 1 megasample per channel enable capture of transient events. Readouts are available directly in units such as g's or PSI, and analysis is available in real-time histograms, trend waveforms, filtering, FFT, integration, and differentiation. Acquisition modes include multi-shot, autocycle, averaging, and persistence. The unit is programmable via IEEE-488.2 and RS-423. **Circle No. 716**

3D Control Device

Logitech, Fremont, CA, offers the Magellan 3D control device that enables Autodesk® users to interactively visualize and edit solid, surface, and wireframe models in real time. The user positions an object with the device, while working on the same object with a mouse in the other hand. The opto-electronic device offers six degrees of freedom and works with RS-232 serial interfaces with no additional power supply necessary. Features include built-in support for Autodesk Mechanical Desktop® 2.0, and AutoCAD® R14 compatibility. The controller translates the user's sense of touch into movement of objects within a 3D space, allowing X, Y, Z, pitch, roll, and yaw movements. **Circle No. 717**

Coatings for Aluminum



NEDOX synergistic surface-enhancement coatings for aluminum from General Magnaplate Corp., Linden, NJ, are formulated to create a protective surface against abrasive wear, humidity, gases, and corrosion by most chemicals. The dry-lubricated, non-stick surface also reduces friction of moving or sliding parts; thickness build-up is as low as 0.0002". Aluminum parts coated with NEDOX can be used in cryogenic applications down to -250° F, as well as in computers and peripherals, communications, electronic equipment, and industrial equipment. **Circle No. 721**

Long-Life Tapes and Films

Teflon®, Kapton®, and FEP tapes and films are available from CS Hyde, Lake Villa, IL. The tapes are designed for longer life and higher output under extreme conditions, and are designed for applications requiring a non-stick surface that is resistant to heat, chemicals, and moisture. Kapton® is used in electrical applications for high dielectric strength, insulation, and conformability. FEP Teflon® tape is optically clear with excellent electrical properties and chemical resistance. **Circle No. 752**

Electric Linear Drives

The OSP-E ball screw drive from Hoerbiger-Origa Corp., Glendale Heights, IL, can be integrated into OEM equipment and factory systems requiring actuation or automation. Based on the Origa System Plus cylinder design, the drive is available in 25-, 32-, and 50-mm bore diameters, with strokes to a maximum of 10 feet. The linear actuator contains a precision ball screw drive that provides both guidance and power transmission. Power comes from an optional or user-supplied motor. A double dovetail channel on three sides of the extrusion allows components to be secured directly to the cylinder, including integral guides, shock absorbers, sensors, and interface mountings. **Circle No. 719**

Pulse/Data Generators

Hewlett-Packard, Palo Alto, CA, has announced the HP 81100 family of pulse/data generators, which provide standard pulses, digital patterns, sequenced and looped data, and multilevel waveforms required for testing the digital and analog function of designs. Four models are available, each with a different frequency range. Performance levels from 80 MHz to 330 MHz generate one- or two-channel digital waveforms. The generators can perform complex digital tests such as IC verification or clock testing of microprocessors, which require precise timing and a frequency of 500 MHz. Fixed delay between trigger-in and signal-out allows timing synchronization within a test setup of different instruments. **Circle No. 720**

Industrial Flat-Panel Display

Interstate Electronics Corp., Anaheim, CA, has released the Sentry-20 SXGA flat-panel display for harsh industrial applications. The 20-inch active matrix liquid crystal display (AMLCD) system has 1280 x 1024 resolution, on-screen digital controls, and MTBF of 20 hours. It can be used for desktop or rack-mount configurations, and meets NEMA 4/12 standards. The system is available with an optional SXGA video input feature. **Circle No. 718**

Pressure Calibrators

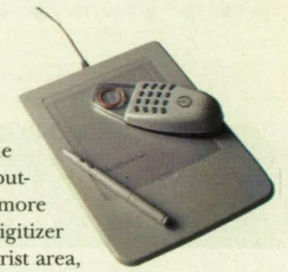
Fluke Corp., Everett, WA, has introduced the Model 716 and 717 handheld pressure calibrators that measure pressure up to 10,000 psi/69 MPa, using any of 27 Fluke 700Pxx Pressure Modules. The Fluke 716 is a lightweight field calibrator designed for a variety of gage, differential, absolute, vacuum, and compound applications. The user can select one of 11 different engineering units for pressure display. The Fluke 717 30G Pressure Calibrator includes an internal 30 PSIG sensor and a 1/8 NPT pressure fitting. Each pressure calibrator offers zero, min, max, and hold functions. They have dust- and splash-resistant cases with EMI shielding, and come with a Fluke-yellow holster and 9V alkaline battery. **Circle No. 722**

Wide-Format Printer

Océ-Engineering Systems, Chicago, IL, has introduced the Océ 9600 printer/plotter/scanner, which is designed to enable CAD/EDMS users and print providers optimal connectivity. It also can be customized to meet specific requirements. The basic unit features a two-roll configuration. Users can get up to seven media sources online, totaling four rolls and three cut-sheet cassettes, or six rolls and one cut-sheet cassette. The cassettes can accommodate pre-punched and pre-printed sheets. The unit produces print sizes from A to E and larger, and features two optional finishing modules: an online folder, with off-line folding capabilities, and a print-receiving tray for larger, unattended production runs. **Circle No. 715**

New on the MARKET

Micro-Format Digitizer



Design Station™ from CalComp Technology, Anaheim, CA, is a micro-format digitizer designed as a high-performance CAD productivity tool for Windows applications. The device features a programmable, 16-button cordless mouse, and takes up no more space than a mousepad. The 8x10" digitizer has a 4x5" active area, an integrated wrist area, and a cordless click-tip pen. The system ships with AccelGraphics' AccelVIEW 3D™ 2.0 editing and viewing software, and CalComp's TemplateWorks™, a template-creation and button-management software tool suite for AutoCAD Release 14. **Circle No. 726**

Easy-Flow Resins

Capron® XFI™ resins from AlliedSignal Plastics, Morristown, NJ, are designed for large-part and thin-wall applications requiring extra flow and impact. The resins can fill large cavity molds without high injection pressures or excessive molded-in stresses. Low viscosity allows the resins to flow into thin-wall parts such as cellular phones, battery housings, handheld electronics, cordless power tools, and electrical components. They are designed to provide impact strength, particularly at knit lines, and offer resistance to chemicals such as gasoline, oils, acetone, and benzene. **Circle No. 728**

Magnesium Notebook

Dolch Computer Systems, Fremont, CA, offers the NotePAC II™ all-metal notebook computer engineered for field operations in harsh environments. It is housed in machined pressure-cast magnesium alloy, is stress-relieved with structural webbing, and features a waterproof keyboard and sealed interface ports. The notebook supports internal applications-specific function modules. Its expansion bay gives the user access to the system's internal bus and power signals. Internal battery power provides up to eight hours of run time. Standard configuration includes a 200-MHz MMX processor, 32 MB RAM, a removable 2.1-GB hard disk drive, and an 11.3" TFT display. Two serial ports, one parallel port, and four expansion bays are provided, in addition to an AC adapter, IrDA and 12 VDC power port, external keyboard, and external mouse and video. **Circle No. 725**

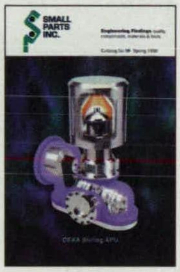
Spectral Light Meter

The LightSpex spectroradiometer from McMahan Research Laboratories, Chapel Hill, NC, measures the entire visible spectrum and calculates, displays, and plots a variety of radiometric and photometric quantities, including irradiance in watts, illuminance in footcandles and lux, correlated color temperature in Kelvin, and spectral power distribution. The unit conforms to ASTM, DCC, ANSI, and IOS standards and procedures. It features an easy-to-read display, and has an internal storage of data that can be downloaded through its RS-232 serial port. Data can be processed with LightSoft Windows NT graphic software, and can be transferred to a common spreadsheet program. **Circle No. 729**

New LITERATURE

Sensor Monitoring System

Vibra-Metrics, Hamden, CT, offers a six-page brochure outlining the Sensor Highway® on-line monitoring system that collects vibration, temperature, pressure, and other parameter data from up to 1,500 sensors installed throughout a facility. The system enables users to incrementally integrate equipment sensors into an existing facility. **Circle No. 730**



Parts & Components

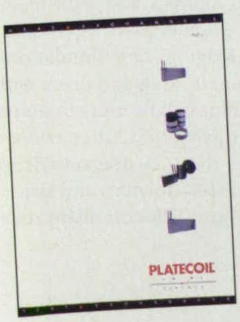
A 448-page catalog from Small Parts, Miami Lakes, FL, lists parts, components, metal and plastic materials, instruments, tools, and other items related to product development and fabrication. Products are available in small or large quantities, and manufacturing services are available for small-quantity prototype development or limited production runs. **Circle No. 731**

Engineered Fasteners

The Engineered Fasteners Division of Eaton Corp., Cleveland, OH, offers a 38-page catalog of Tinnerman® fasteners and parts, including self-locking fasteners, self-retaining fasteners, multiple-thread engaging nut and bolt fasteners, and one-piece, self-locking stud receivers. Also featured are one-piece, self-sufficient clips; clamps; and plastic fasteners. **Circle No. 732**

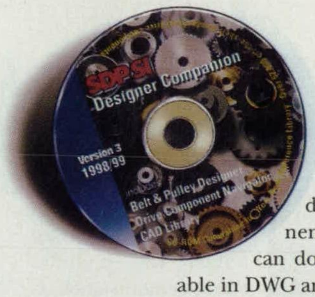
Vacuum Components

Ceramaseal, New Lebanon, NY, has released a 20-page catalog of components designed for thin-film coatings and other high-vacuum applications. Products include baseplate feedthroughs, crystal sensors, crystal-sensor feedthroughs and assemblies, cables, plugs, and contacts. The high-vacuum components are manufactured with 304 stainless steel. Connections are made with ceramic-to-metal seals. **Circle No. 733**



Heat Exchangers

A 12-page brochure from Tranter, Augusta, GA, describes Platecoil® prime surface heat exchangers. Products include immersion heaters and coolers, jacketed tanks, bayonet and suction heaters, refrigeration coolers, storage-tank heaters, and cryogenic shrouds. Also included are selection and temperature charts, and applications. **Circle No. 734**

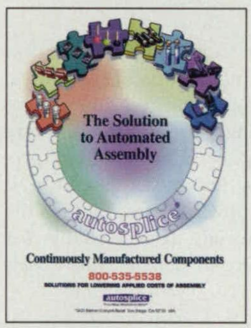


Component CAD Drawings

Stock Drive Products/Sterling Instrument, New Hyde Park, NY, has released the Designer Companion D700, a CD-ROM that includes CAD drawings for more than 45,600 components offered by the company. Engineers can download the drawings, which are available in DWG and DXF formats. Drawings of gears, belt and chain drives, shafts, bearings, couplings, gearheads, brakes and clutches, and motors are included. **Circle No. 735**

All-Metal Locknuts

SPS Technologies Aerospace Fasteners Group, Jenkintown, PA, has issued an 80-page engineering guide on FLEXLOC® one-piece, all-metal prevailing torque locknuts that resist impact, shock, and vibration. The guide features FLEXLOC slotted locknuts, clinch nuts, and FLEXITHREAD® non-locking and self-locking swage nuts. **Circle No. 736**



Automated Assembly

Autosplice, San Diego, CA, offers a four-page brochure describing Continuous Component Processing (CCP) technology, which provides a continuously reeled format to automate assembly, processing, and placement of molded components, devices, or sub-assemblies. A Continuously Reeled Header System is designed for automated placement of pin header connectors onto printed circuit boards. **Circle No. 737**

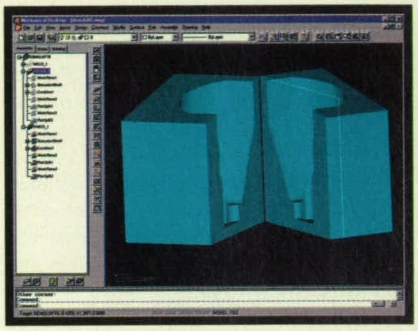
Video/Imaging System

A brochure from Feral Industries, Overland Park, KS, describes the QS-400 Quad Split image display and resizing device, which combines four video inputs into one video output, enabling users to view and manipulate multiple images on one screen. The system is available in standalone and PCB-level desktop video models. **Circle No. 738**

Gearmotor Selection

Bodine Electric, Chicago, IL, offers the SG Right Angle Gearmotor Guide, which includes schematics of three different configurations: an induction AC gearmotor, a permanent magnet DC gearmotor, and a brushless DC gearmotor. Technical charts list data for continuous and peak torque, radial load, speed, current amps, and wiring differences. **Circle No. 739**

New on DISK



Enhanced Solid Modeling

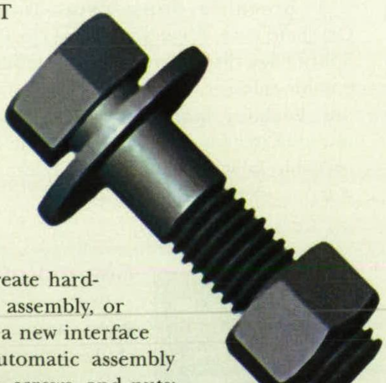
Mechanical Desktop® 3.0 solid/surface modeling software for mechanical design from Autodesk, San Rafael, CA, includes enhancements such as face draft/parting lines, and the ability to create free-form parametric shapes with a new lofting capability. Built around Spatial Technology's ACIS 4.2 solid modeling kernel, the software includes 3D sweep, parametric 3D lofting, feature suppression, and part split. A graphical parts and assembly drawing browser enables users to reorder a feature at any point in the design process via drag-and-drop. Feature suppression allows users to suppress features that are not important to their current task, allowing creation and modification of large, complex models without waiting for regeneration or rendering of unnecessary details. The program is available for Windows 95/NT. **Circle No. 712**

Simulation Tools

Version 4 of Extend simulation software from Imagine That, San Jose, CA, is designed to enable virtual testing of "what-if" scenarios, prototype designs, analysis of equipment options, and other simulations. It includes drag-and-drop modeling, top-down/bottom-up hierarchy, animation, control-panel interface, and a built-in programming environment. Enhancements include a hot-link to Microsoft® Office, the ability to import AutoCAD files, toolbar file and editing accelerators, and online tutorials. It is available for Windows 98, 95, NT, and 3.1; and Macintosh 68020+ and Power Macintosh. **Circle No. 705**

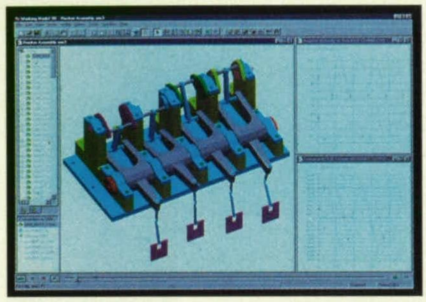
Parametric Parts Library

Solid Mech 2.0, a parametric parts library from EMT Software, Bellingham, WA, is now compatible with SolidWorks98. The parts library includes fasteners, bearings, and steel shapes created from tables based on industry standards such as ANSI/ASME, ASTM, ISO, JIS, DIN, AS, and BSI. Users can immediately create hardware without opening a part, assembly, or drawing. The library features a new interface with dockable toolbar; an automatic assembly feature for washers with bolts, screws, and nuts; and additions to the hardware library of parts. Parts libraries include aluminum shapes, retaining rings, rivets, seals, O-rings, and keys. The software is network-ready and Y2K-compliant. **Circle No. 706**



Enhanced Mechanical Software

Knowledge Revolution, San Mateo, CA, has released Working Model® 3D 4.0 mechanical engineering simulation software, which features collision detection algorithms, seamless integration with Pro/ENGINEER, STL import capability that enables interfacing to Windows NT CAD systems, and user interface enhancements. Pro/ENGINEER users can export CAD models into Working Model through Automatic Constraint Mapping. STL import allows integration with Windows CAD programs such as Unigraphics® from Unigraphics Solutions, and Eureka Gold from Cad.Lab. Specified motion allows objects to move according to formulas or tables, rather than physics.
Circle No. 703



Human-Simulation Software

Transom™ Jack® 2.0 human modeling and simulation software from Transom Technologies, Ann Arbor, MI, features support for platforms such as Intel PCs running Windows NT. Other enhancements include web and network links, improved file translation, an intuitive graphical user interface, and additional human figures such as Transom Jill™, an adult female figure. Users create or import environments, insert virtual humans, give them tasks, and evaluate performance. The digital humans tell engineers what they can see and reach, how comfortable they are, when and how injuries occur, and when virtual fatigue sets in. **Circle No. 702**

Statistical Computing

SYSTAT 8.0 statistics and graphics software from SPSS, Chicago, IL, includes new features such as additional spatial statistics that allow users to perform complex statistical analysis and data management with graphic capabilities. The program evaluates geostatistical models with 2D and 3D variogram, Kriging, and simulation. The browser interface offers enhanced toolbars, drag-and-drop, and right-mouse support. Graph-editing capabilities allow users to point and click to change graph location, scale or axis labels, titles, colors, and symbols. The data editor manipulates data via drag-and-drop variables, resizing columns, and changing display formats and styles. New data display options include currency and Y2K-compliant date formats. **Circle No. 700**

Design/Modeling Software

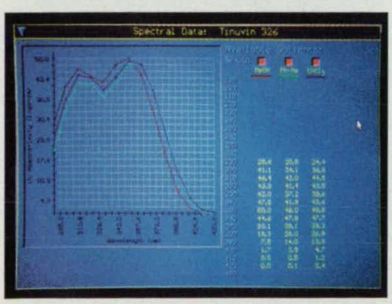
Ditek Software Corp., Manchester, NH, has announced DynaCADD® 98 2D/3D drafting, design, rendering, and modeling software that features customizable toolboxes, graphic figure libraries, auto-snap connections, dynamic entity insertion, and the ability to open multiple documents simultaneously. Additions include support for DWG AutoCAD R14 formats, 16-bit raster images, paper-space entities, and large-format digitizers. **Circle No. 707**

Document Management

Cyco Software, Atlanta, GA, offers AutoManager® WorkFlow™ Version 6 document management software for the CAD and engineering environment. Enhancements include support for Autodesk's Mechanical Desktop® 2.0, IntelliCAD® 98, and direct scanner compatibility. A new AutoManager Internet Publishing Tool transforms AM-WorkFlow's Card View into HTML. With the AutoManager Plug-in, CAD drawings published on the Web can be downloaded and viewed inside the browser. Users can then view, zoom, scale, pan, and print the document without opening the native application. **Circle No. 708**

Interactive 3D Graphics

Wolfram Research, Champaign, IL, has released Dynamic Visualizer for the Mathematica Applications Library. The application enables interactive manipulation, rendering, and animation of 3D graphics objects. Objects of arbitrary size and complexity can be rendered in real time via standard Mathematica commands. Users can direct and alter each object's location, orientation, and speed of rotation with the mouse or keyboard. Options include point clouds, wireframes, and filled polygons with hidden surface removal. Dynamic Visualizer requires Mathematica 3 or higher, and is available for Windows and Macintosh platforms. **Circle No. 701**



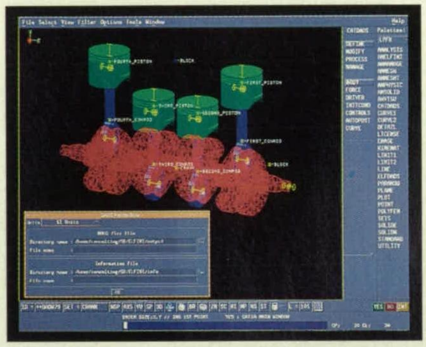
UV Absorber Database

Ultra V™ version 1.00 from CleoSci, St. Paul, MN, is a database of ultraviolet absorbers used in polymers and plastics, paints and coatings, and other industries. The database includes more than 50 known UV absorbers and includes a trade-name cross-reference between similar products and their manufacturers; a Beer's Law calculator for determining coating requirements; plots of wavelength vs. absorptivity; dynamic and isothermal TGA data; and information on uses, applications, and toxicity. The program offers both DOS and Windows/Windows 95 support. **Circle No. 709**

New on DISK

Software Automates Meshing

Raindrop Geomagic®, Champaign, IL, has released geomagicWrap® version 2.0 software that automatically "wraps" an accurate meshed surface around arbitrary point-cloud data. The resulting surface is triangulated and topologically consistent. It also imports data from virtually all 3D scanners and digitizers. Enhancements include three plug-in modules for software customization; IGES 126 output for spline curves on polygonal models; surface decimation for WRP, OBJ, and STL models; and a software-development kit. The software runs on Windows NT, Windows 95, and Silicon Graphics workstations. **Circle No. 704**



Mechanical Simulation

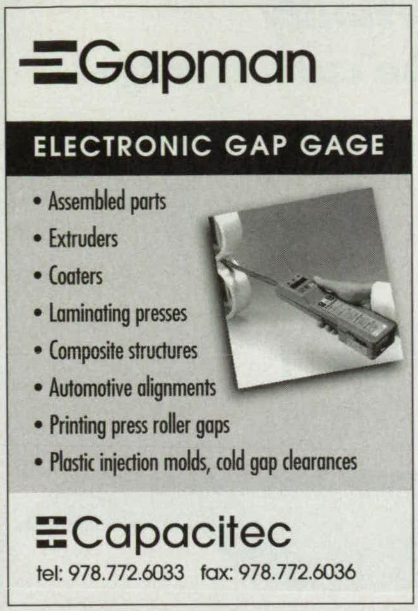
Computer Aided Design Software (CADSI®), Coralville, IA, offers CATDADS™ version 9.0 for design simulation embedded in CATIA™, and a CATIA Elfini interface. The program enables analysis of real-world behavior of mechanical systems directly in CATIA. Simulation results are viewed as graphs and animation to verify fit, performance, and reliability of product designs. The program includes an implicit integrator, additional driver constraints, enhanced friction modeling, and interactive simulation. The CATIA Elfini interface is used to perform flexible body analysis with CATDADS using Dassault Systèmes' FEA software, Elfini. **Circle No. 710**

Enterprise-Wide Modeling

MicroStation/J™ enterprise engineering modeling software from Bentley Systems, Exton, PA, includes Parasolid® solid modeling, a native Java™ environment, and the engineering functionality of the MicroStation®, TriForma®, MicroStation Modeler®, or MicroStation GeoGraphics® software products. The Parasolid user interface, SmartSolids™, enables manipulation and visualization of solid models. Other additions include Web-enabled engineering, full OLE support, batch plotting, digital signatures, visualization, imaging, and image management. MicroStation/J is compatible with previous releases and editions of MicroStation. **Circle No. 711**

System Simulation

SIMPLORER 4.0 from Magsoft Corp., Troy, NY, is a Windows 95/NT mixed-language simulation suite for software development that allows users to simultaneously view and modify a diagram of a model and the outputs of the simulation without reformatting. The software includes context-sensitive online help and an integrated database. A symbol editor enables users to generate their own symbols, and information about all main functions can be accessed via right-mouse click. A text editor features drag-and-drop capability, which allows a symbol to be lifted from a graphical input of the library and the correct SML text to be dropped into a text file. The 32-bit simulation with Viewtool allows immediate output of results as they are calculated. **Circle No. 753**



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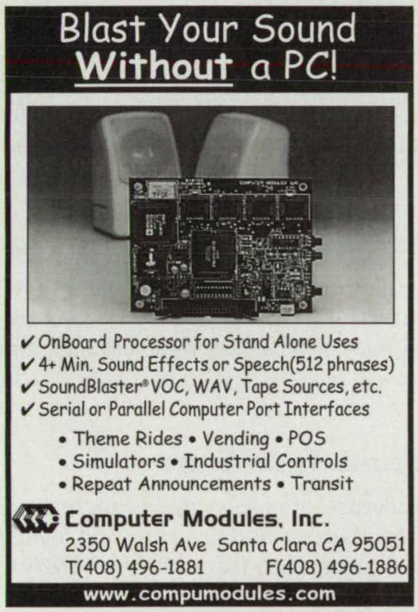

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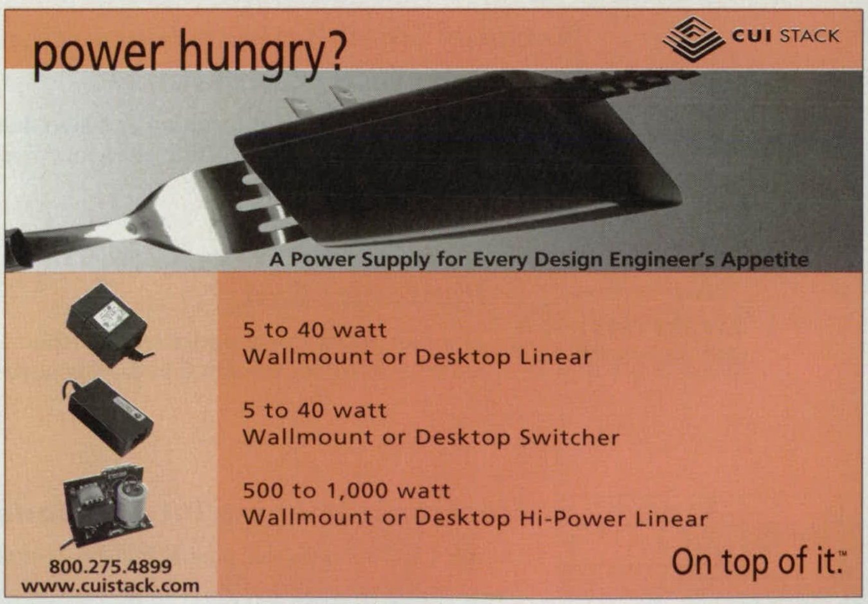
For More Information Circle No. 587



For More Information Circle No. 586

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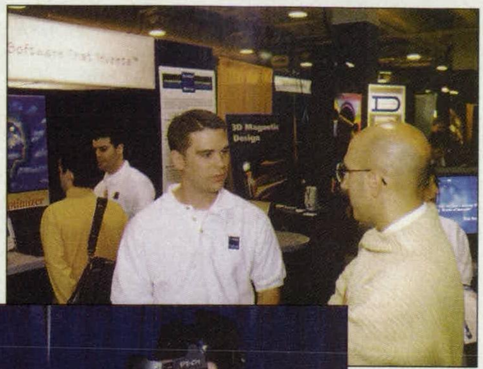

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